

OPERATION & MAINTENANCE
INSTRUCTIONS
for
MECHANALYSIS
MODEL 308
VIBRATION SOUND LEVEL METER

**OPERATION & MAINTENANCE
INSTRUCTIONS
for
MECHANALYSIS
MODEL 308
VIBRATION SOUND LEVEL METER**

Effective S/N 175 & on

IRD Mechanalysis, Inc.

Subsidiary of H. H. Robertson Company

6150 Huntley Road
Columbus, Ohio 43229

Offices in USA, Canada, United Kingdom, Western Europe and Australia

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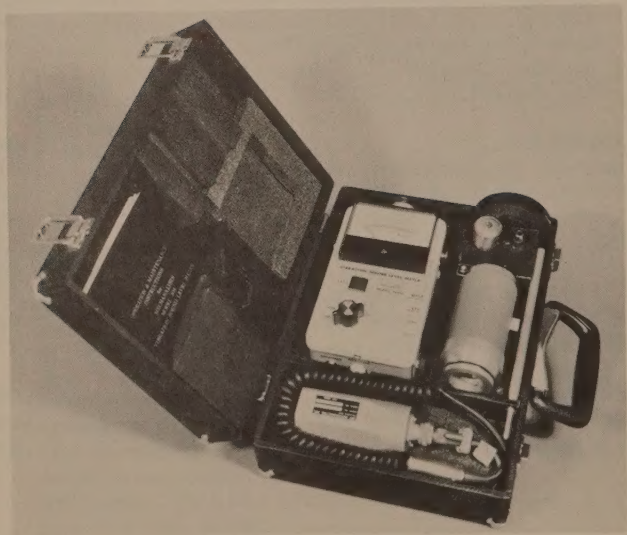


Figure 1. Model 308 Vibration/Sound Level Meter

INTRODUCTION

The Model 308 Vibration/Sound Level Meter, by combining in a single instrument the capability of measuring either vibration or sound, provides a unique three-fold approach to the control of machinery problems and noise pollution.

1. Conditions in a machine that can eventually result in breakdown can be detected by periodic vibration readings of the machine, using the Model 308. As periodic readings increase trouble is indicated. The cause of the trouble can then be analyzed and corrected, preferably with the use of a Vibration Analyzer/Dynamic Balancer instrument.

2. As a general rule, an increase in the vibration of a machine will also result in increased noise levels near the machine. Using the Model 308 for periodic noise measurements in the immediate area of specific machines can indicate developing trouble in the same manner as vibration readings. In many cases one type of measurement will confirm the trouble indicated by the other. Additionally, it is important to note that periodic noise measurements can uncover some types of machinery problems which might not be detected by vibration measurements.

3. The Model 308 provides the means for carrying out an effective program of noise pollution measurement and control. Such programs, whether elective or to achieve compliance with Local, State or Federal "Standards," imply the use of a sound level meter which will provide consistent accuracy as related to accepted measurement standards. To provide this accuracy, the Model 308 is designed

to meet or exceed the specifications of American National Standards Institute (ANSI) S1.4-1971 for Type 2 Sound Level Meters, and International Electrotechnical Commission (IEC) Recommendation 123 (1961).

This manual fully describes the Model 308 Vibration/Sound Level Meter and provides details on its operation, application and maintenance. It is recommended that the manual be read throughout before the instrument is used.

Combined with the knowledge represented in this manual, the Model 308 is an effective and valuable tool for dealing with many types of routine vibration and noise problems. However, problems beyond the "routine" require more sophisticated equipment and more knowledge. IRD Mechanalysis offers both. An extensive line of analysis equipment (including Real Time) is available, and is backed by complete and complimentary training courses in both vibration and sound, at basic and advanced levels. Basic courses are available in all Mechanalysis Districts, worldwide.

DESCRIPTION

GENERAL

The Model 308 Vibration/Sound Level Meter, figure 1, provides the capability of measuring either vibration or sound in one compact, easy to use instrument. The Model 308M Vibration/Sound Level Meter (not illustrated) is identical to Model 308 except that vibration amplitude is read in Metric units instead of English units. All information relative to Model 308 applies equally to Model 308M except where specifically stated otherwise. The portable, battery-powered meter is supplied with a rugged carrying case which also holds the instrument manual, microphone, vibration pickup, and pickup accessories provided. A carrying strap for the meter simplifies measurements and data recording. Figures 2 and 3 illustrate the Model 308 being used as a vibration meter and as a sound level meter.

The Model 308 is designed to meet the specifications of ANSI Standard S1.4-1971 and IEC Recommendation 123 (1961). Micro-power integrated circuitry in the meter ensures reliability, extended battery life, and linear accuracy over a wide frequency range.

Specific details of controls and components are given in the remaining paragraphs of this section. Meter features are illustrated in figure 4.

MEASUREMENT MODE PUSHBUTTONS

Two vibration measurement modes (black DISP and VEL pushbuttons) and three sound level measurement



Figure 2. Model 308 Used as Vibration Meter

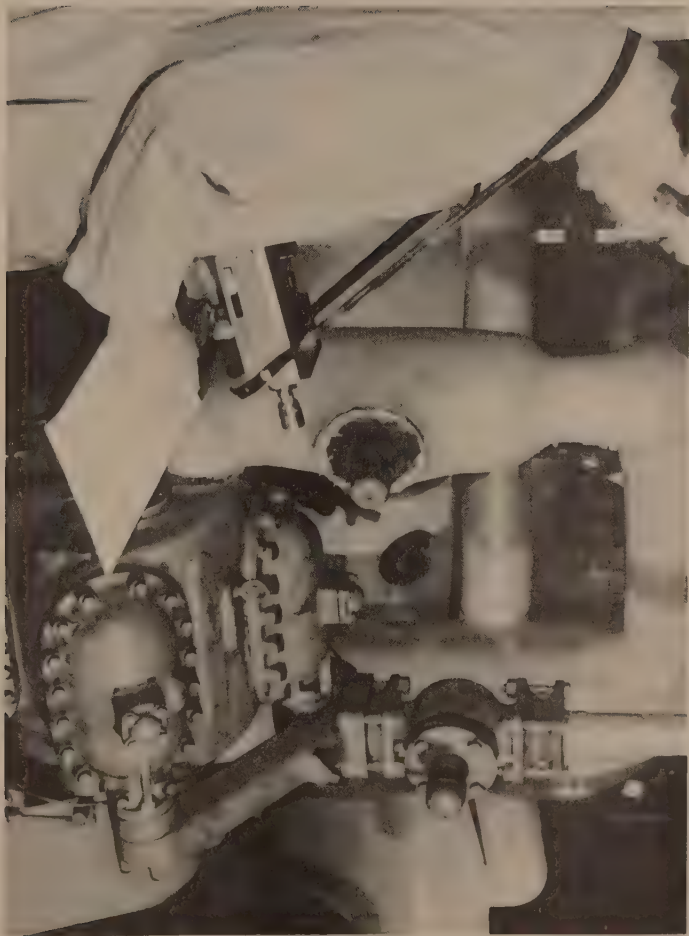


Figure 3. Model 308 Used as Sound Level Meter

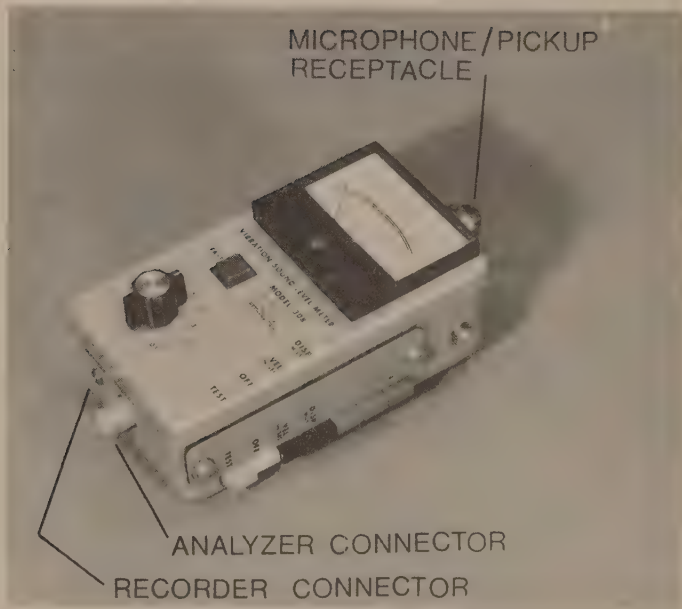


Figure 4. Instrument Features

modes (red A, B and C pushbuttons) may be selected. (The A, B and C modes select, respectively, the A, B and C frequency response "weighting" networks in the meter.) The five mode pushbuttons are "ganged" with the white OFF pushbutton; that is, depressing any one of the six pushbuttons will automatically return any previously depressed pushbutton to the "out" position. The gray TEST pushbutton operates independently; when depressed, battery condition is satisfactory if the amplitude meter reads within the TEST area on the meter face. (The TEST function does not work when the OFF pushbutton is depressed.)

FAST (RESPONSE) PUSHBUTTON

When used as a sound level meter, the meter circuitry is normally set up for relatively slow readout response to changes in the sound levels being measured. The amplitude meter readings are steadier, and intermittent rapid level changes of the sound being measured will be somewhat "averaged" in the readout. However, when it is desired to observe the occurrence or amount of rapid level changes, depressing the red spring-loaded FAST pushbutton alters the meter circuitry to respond with greater speed.

AMPLITUDE METER AND RANGE SELECTOR

The amplitude meter has three scales. The two black scales, 0 to 1 and 0 to 3, are for vibration readings; the red -5 to +10 dB scale is for sound level readings.

Interpretation of the amplitude meter reading is dependent on both the amplitude range selector setting and the measurement mode selected. The eight black-numbered ranges are for vibration readings, and permit a total readout range of 0 to 100 mils (0 to 3000 microns, Model 308M) of peak-to-peak displacement with the DISP mode selected, or 0 to 100 inches per second (0 to 3000 millimeters per second, Model 308M) of peak vibration velocity with the VEL mode selected. (1 mil = 0.001 inch; 1 micron = 1×10^{-6} meter.) The nine red-numbered range settings are for sound level readings, and permit a total readout range of 45 to 140 decibels (dB) (re 0.0002 microbar), with either the A, B or C weighting network selected. Details on interpretation of meter readings are

given in the Operation section.

MICROPHONE/PICKUP RECEPTACLE

The MICROPHONE/PICKUP receptacle accepts either the microphone or the vibration pickup cable connector. The receptacle is designed to positively lock the mating connector when fully seated; the release button on the receptacle must be depressed to remove the microphone or pickup cable connector.

ANALYZER AND RECORDER OUTPUT CONNECTORS

The ANALYZER and RECORDER output connectors are shown in figure 4. The ANALYZER output provides a means of frequency analysis of sound level measurements. The output is interconnected with the pickup input of a Mechanalysis Vibration Analyzer/Dynamic Balancer (Model 330, 340 or 350). The analyzer filter is then tuned to locate the specific frequencies contributing to the overall amplitude indicated on the Model 308. The amplitude of each frequency located can also be determined.

The RECORDER output provides a means of obtaining Amplitude vs Time recordings of vibration or sound levels monitored with the Model 308. The output is a d-c voltage which is proportional to the amplitude of the vibration or sound level being monitored, and is compatible with a variety of d-c recorders. A jack which mates with the RECORDER connector is provided as standard equipment with the meter. Recordings of vibration levels can be very useful for purposes such as studying the effects of various changes (load, temperature, etc.) or for more continuous monitor-

ing of a machine when the measurements are approaching critical levels. Sound-level recordings are similarly useful for machinery problems, and for purposes such as determining maximum area noise levels to which personnel are or may be exposed, and duration of exposure.

Additional details regarding the ANALYZER and RECORDER outputs are given in the Operation and Specifications sections.

BATTERIES AND COMPARTMENT

The battery compartment is located behind the access cover plate above the mode selector push-buttons. Two 8.4-volt mercury batteries are supplied; polarized snap-on connectors permit foolproof battery installation. The access cover is secured with two captive screws.

VIBRATION PICKUP, PROBE AND CABLE

The Model 544 Vibration Pickup may be used with or without the 9-inch accessory probe provided. The pickup is interconnected with the meter MICROPHONE/PICKUP receptacle using the 6-foot retractile cable. The pickup produces an electrical output voltage proportional to the vibration velocity of the machine part to which it is applied. (Circuitry in the meter converts the velocity-related signal to a displacement-related signal, when the DISP mode is selected.) Complete characteristics are given in the Specifications section.

The pickup may be mounted using a 1/4-28 stud (welded or threaded to the machine part) to mate

with the hole in the pickup end cap. It may also be hand-held. Mounting position does not affect sensitivity or accuracy. For hand-held measurements, the end of the pickup may be applied directly to the point of interest, or the 9-inch probe may be installed; the probe permits better access to hard-to-reach points. Optional Vise Grip or Magnetic Holders permit quick, "hands-free" application of the pickup.

MICROPHONE

The microphone is omnidirectional (equally sensitive to sound arriving from all directions) and utilizes a ceramic sensing element. The microphone features a wide frequency response and is designed strictly for sound level measurements. (See Specifications section for additional details.) The microphone installs directly in the MICROPHONE/PICKUP receptacle, thus eliminating cable noise or cable impedance matching problems. (Use of an extender cable for connecting the microphone to the Model 308 is not recommended.)

CARRYING CASE

The carrying case is divided into compartments for the instrument, operation manual, and various accessories. Foam padding in the compartments provide additional protection for the meter and accessories. A projection in the meter compartment depresses the OFF pushbutton when the meter is placed in the compartment. Space is provided in the carrying case for two spare meter batteries, and for the optional Sound Level Calibrator (see "Optional Accessories").

SPECIFICATIONS

GENERAL INSTRUMENT SPECIFICATIONS

RECORDER Output:	D-C output proportional to amplitude meter reading. Compatible with strip chart recorders having 200 microampere d-c sensitivity, 5000 ohms resistance.
ANALYZER Output:	A-C output proportional to meter reading. Full-scale a-c output is 764 millivolts (301 millivolts, Model 308M) rms into an impedance of 100,000 ohms. (Compatible with Mechanalysis Model 330, 340 or 350 Vibration Analyzer/Dynamic Balancer instruments or conventional oscilloscopes.)
Battery requirements:	Two NEDA Type 1604 8.4-volt or 9-volt batteries. (Two 8.4-volt mercury batteries supplied.)
Suitable Battery Types and Average Life:	1. Mercury; approximately 500 hours. (Mallory Duracell TR 146X; Eveready E146X; Burgess 146X.) 2. Alkaline; approximately 300 hours. (Mallory MN1604; RCA 1323.) 3. Zinc-Carbon; approximately 150 hours. (Eveready 216; Burgess 2U6; RCA VS323; Mallory M1604.)
Battery Condition:	TEST pushbutton provides meter indication of battery condition.

Temperature 0°F to 150°F.
Range:

Overall Instrument 9 x 4-5/8 x 3-1/4
Dimensions: inches.

Carrying Case 13-1/4 x 10-1/4 x
4-1/2 inches.

Weight: Instrument with batteries: 2 pounds.

Instrument with carrying case and
accessories: 8 pounds.

Shipping weight: 10 pounds.

INSTRUMENT AS VIBRATION METER

Frequency 720 to 60,000 CPM (12 to 1000 Hz),
Range: with Model 544 Vibration Pickup
 used as sensing transducer.
 (Instrument range is 300 to 600,000
 CPM, or 5 to 10,000 Hz.)

Maximum Peak-to-Peak Displacement: 0.001
Sensitivity: mils (0.03 microns, Model 308M).

Peak Velocity: 0.001 inch per
second (0.03 millimeter per second,
Model 308M).

Amplitude Peak-to-Peak Displacement: 0 to
Ranges: 100 mils (0 to 3000 microns, Model
 308M), in eight overlapping ranges.

Peak Velocity: 0 to 100 inches per

second (0 to 3000 millimeters per second, Model 308M), in eight overlapping ranges.

INSTRUMENT AS SOUND LEVEL METER

Design Standards: Meets or exceeds ANSI S1.4-1971 (Type 2) and IEC Recommendation 123 (1961).

Frequency Response Weighting Networks: A, B and C, per ANSI S1.4-1971.

Frequency Range: 20 to 10,000 Hz (1200 to 600,000 CPM), with Microphone Part No. 5294 used as sensing transducer. (Instrument range is 5 to 10,000 Hz, or 300 to 600,000 CPM.)

Amplitude Range: 45 to 140 dB (re 0.0002 microbar) in nine overlapping ranges, for A, B or C weighting networks.

Meter Response Rates: "Slow" and "Fast" per ANSI S1.4-1971. Slow response except when FAST pushbutton is depressed.

MODEL 544 VIBRATION PICKUP SPECIFICATIONS

Type: Seismic velocity; self-generating. The sensitive axis is the longitudinal axis, and is perpendicular to the mounting surface.

Output	240 ($\pm$ 24) millivolts ac (rms) out-
Sensitivity:	put for a peak-to-peak displacement of 0.001 inch (1 mil) at 100 Hz (6000 CPM). This corresponds to a Velocity Constant of 1.08 volts ac (peak) output per inch per second of peak vibration velocity. Sensi- tivity is unaffected by orientation.
Orientation:	May be used in any mounting position without adjustment or correction.
Frequency Response:	Room ambient ($\pm$ 77°F): $\pm$ 8% over the frequency range 12-1000 Hz; down 8% $\pm$ 13% @ 10 Hz; pickup fre- quency response drops exponentially at lower frequencies. Elevated ambient (+ 250°F): $\pm$ 13% over the frequency range 12-1000 Hz. The above limits are total variations for any mounting position of the pickup.
Transverse Response:	Average transverse response less than 5% of the longitudinal re- sponse, over the frequency range 10-1000 Hz.
Natural Resonant Frequency:	16 Hz critically damped at + 77°F.
Amplitude Range:	Minimum: limited only by amplifier gain and noise level. Maximum: 0.125 inch peak-to-peak displacement up to 70 Hz; 30 g's

peak acceleration above 70 Hz.

Amplitude $\pm$ 5% from 0.0001 to 0.1 inch peak-
 Linearity: to-peak displacement.

Recommended 2.5 g's at 20 Hz to 30 g's above
 Maximum 70 Hz, continuous.
 Acceleration:

Damping Char- The pickup has a damping factor of
 acteristic: approximately 0.7 which results in
 essentially flat operation over the
 frequency range. This provides
 improved accuracy and improved
 transient response for low frequency
 operation.

Magnetic Without shielding: 0.15 in/sec/
 Field gauss.
 Sensitivity: With 10:1 Shield (Part No. 1157):
 0.015 in/sec/gauss.
 With 100:1 Shield (Part No. 3563):
 0.0015 in/sec/gauss.

Electrical 2,000 ($\pm$ 200) ohms DC resistance.
 Impedance:

Temperature -40^oF to 500^oF.
 Range:

Humidity: Pickup case and connector are water-
 tight. Pickup performance is
 unaffected by humidity, condensa-
 tion, and immersion in water for
 short periods.

Construction: High-temperature solder connections.
Machined aluminum case.

Mounting: One 1/4-28 x 1/4" tapped hole for
mounting to 1/4-28 stud in machine
or in suitable bracket.

Weight & Dimensions: 21 ounces. 4-7/8" long x 2-3/16"
diameter.

Output Connector: ITT Cannon GS02-10SL-4P-111 High-
Temperature, Hermetically Sealed
(or equivalent).

MICROPHONE (PART NO. 5294) SPECIFICATIONS

Type: Piezoelectric - ceramic; omni-
directional.

Electrical Impedance: 460 pf capacitive (at 77°F).

Frequency Response: 20 to 10,000 Hz.

Sensitivity: -60 ($\pm$ 2) dB re 1 volt per microbar.

Distortion: 1% or less total harmonic distortion
at 150 dB sound pressure level.

Temperature Range: -50°F to +150°F.

Sound Pressure Extremes: Cartridge will withstand momentary
sound pressures in excess of 160 dB
sound pressure level and 150 dB

Extremes: sound pressure level for at least 100 hours with no measurable change in characteristics.

Humidity: Cartridge will withstand 95 to 100% humidity for at least 1000 hours without deterioration.

STANDARD ACCESSORIES

- 1 - Model 544 Vibration Pickup, Part No. 4526
- 1 - Straight Probe, Part No. 1103
- 1 - 6 foot Retractable Pickup Cable, Part No. 9288
- 1 - Microphone, Part No. 5294
- 1 - Carrying Strap, Part No. 3829
- 1 - Operation Manual
- 1 - Plug, RECORDER Output, Part No. 9361
- 1 - Carrying Case, Part No. 9375

OPTIONAL ACCESSORIES

Spare Battery, 8.4-volt Mercury, Part No. 9291.
(2 Required.)*

Sound Level Calibrator, Part No. 9404. (Secondary standard introduces known sound pressure level directly to microphone; use ensures consistent accuracy of sound level measurements.)

D-C Recorder, Strip Chart, Part No. 9405. For Vibration or Sound Level recordings, utilizing Model 308 RECORDER output. 117-volt, 60-Hz operation (234-volt, 50-Hz operation available

* See "General Instrument Specifications" for suitable battery types available locally.

on request). Ten selectable chart-drive speeds: 3/4, 1-1/2, 3, 6 and 12 inches per hour, and 3/4, 1-1/2, 3, 6 and 12 inches per minute. (Maximum of 68 days continuous recording at 3/4 inch per hour.) Visual readout scales of 0 to 1 (linear) and -5 to +10 (dB, logarithmic) on recorder. Includes Accessory Kit (ink, pen filler, pen cleaner); one 103-foot roll of linear chart paper (0 to 1 scale); one 103-foot roll of logarithmic chart paper (-5 to +10 dB scale); one Recorder-to-Model 308 Interconnecting Cable, Part No. 9494; and one instruction manual. Additional details and specifications available on request.

Recorder Chart Paper, 103-foot roll, 0 to 1 linear scaling, Part No. 9406. (For 9405 Recorder.)

Recorder Chart Paper, 103-foot roll, -5 to +10 dB logarithmic scaling, Part No. 9469. (For 9405 Recorder.)

Magnetic Pickup Holder, Part No. 4332. (For use with Model 544 Vibration Pickup.)

Vise Grip Pickup Holder, Part No. 1821. (For use with Model 544 Vibration Pickup.)

Amplitude Meter Scale Overlay. (Provides dB scale on analyzer amplitude meter for performing sound analyses.)

Model 330 - Overlay Part No. 5337
Model 340 - Overlay Part No. 5868
Model 350 - Overlay Part No. 9558
Model 600 - Overlay Part No. 9688

OPERATION

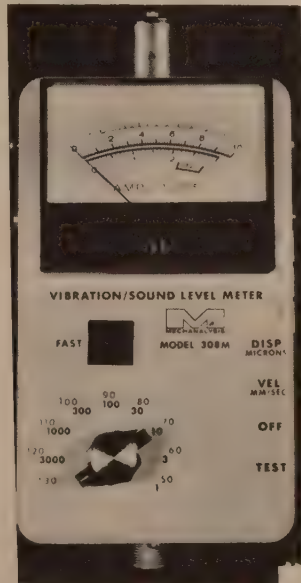
GENERAL

The scope of this section is limited to basic operating details. Actual instrument usage is described in practical terms in the following two sections, Vibration Measurement Techniques and Applications, and Sound Level Measurement Techniques and Applications.

Figure 5 illustrates controls and other meter details which will be discussed in this section.



English Unit



Metric Unit

Figure 5. Model 308 Panel Details

VIBRATION MEASUREMENT

The following steps are the basic requirements for preparing and using the meter for vibration measurements:

1. Confirm that the OFF pushbutton is depressed. Attach the carrying strap to the studs on the sides of the meter.

2. Connect the vibration pickup to the meter with the pickup cable. Press cable connector firmly into PICKUP receptacle to ensure that lock engages.

3. Select desired DISP or VEL measurement mode.

4. Depress the TEST pushbutton and confirm readout within the TEST area on the amplitude meter. If readout is below TEST area replace batteries as described in Maintenance section.

5. Apply the pickup to the point to be measured. (If pickup is to be threaded onto a mounting stud, disconnect cable at meter end.)

6. For each point to be measured set the range selector to successively lower (or higher) ranges until a meter reading within the upper two-thirds of the black scales is obtained. (This provides better meter accuracy than readings in the lower third of the scales.) The amplitude reading will be in mils (microns, Model 308M) of peak-to-peak displacement, or in inches per second (millimeters per second, Model 308M) of peak velocity, depending on whether the DISP or VEL mode is selected.

The black 0 to 1 scale is read if the range selected is ".1", "1", "10" or "100" ("1", "10", "100" or "1000", Model 308M), and the black 0 to 3 scale is read if the range selected is ".03", ".3", "3" or "30" ("3", "30", "300" or "3000", Model 308M). The meter full-scale value is equal to the range selected. For example, a reading of 2 on the 0 to 3 scale represents a value of 2 if the "3" range is selected, or a value of 20 if the "30" range is selected. Similarly, a reading of 0.6 on the 0 to 1 scale represents a value of 60 if the "100" range is selected.

7. Record the value of each measurement on a suitable data form, such as the one shown in figure 13 of the next section. (This form provides space for entering all pertinent information required, including sound level measurements.)

8. If the meter is to be used for an extended period of time, recheck the batteries once each hour and at the end of the use period. This practice will help to ensure consistently accurate readings.

SOUND LEVEL MEASUREMENT

The following steps are the basic requirements for preparing and using the meter for sound level measurements:

1. Confirm that OFF pushbutton is depressed. Attach the carrying strap to the studs on the sides of the meter.

2. Install the microphone in the MICROPHONE receptacle; press in firmly to ensure that lock

engages.

3. Select desired A, B or C weighting network.

4. Depress the TEST pushbutton and confirm readout within the TEST area on the amplitude meter. If readout is below TEST area replace batteries as described in Maintenance section.

NOTE

It may be desirable to check the meter for proper sound level calibration prior to each day's usage (with Sound Level Calibrator, Part No. 9404). If this is the case, refer to "Accuracy Test - Sound" in the Maintenance section.

5. Place the meter in position for the measurement, with microphone properly oriented.

6. For each measurement position, set the range selector to successively lower (or higher) ranges until a meter reading within 0 to +10 on the red dB scale is obtained. (This provides better meter accuracy than when readings are between -5 to 0 on the scale.) The value of the dB scale reading is added to the value of the range selector red position number ("50", "60", "70", etc.), to obtain the sound level reading in dB. With a range setting of "70", a scale value of +5 would indicate a sound level of 75 dB, and a scale value of -2 would indicate a sound level of 68 dB. (In the last case, selecting the "60" range would result in a scale value of +8 dB, thus giving the same 68 dB result, but with better meter accuracy

and scale readability.)

7. Record each measurement on a suitable data form which has space to include all other information pertinent to the measurement. When recording measurements, the weighting network (A, B, C) used must be noted on the data sheet, or with the individual measurement values as indicated in the following examples: 79 dB(A); 85 dB(B), 92 dB(C), etc. If the measurements are being taken as part of a machinery preventive maintenance program, a dual-purpose form with space for both sound and vibration readings may be used (see figure 13 in the following section).

8. If the meter is to be used for an extended period of time recheck the batteries once each hour and at the end of the use period. This practice will help to ensure consistently accurate readings.

Using FAST Response Pushbutton

If the sound level being measured is not relatively constant, and has short-duration "peaks," a better approximation of the highest sound level will be obtained by depressing the FAST response pushbutton. This reduces the amount of electrical meter damping which is normally in the circuit to provide "slow" response. (Slow" and "Fast" response rates are as defined by ANSI.)

UTILIZING RECORDER OUTPUT

The RECORDER output is a d-c voltage which varies directly in proportion to the amplitude meter reading. The output may be used to obtain Ampli-

tude vs Time recordings of either vibration or sound levels. The Mechanalysis D-C Recorder (Part No. 9405) is ideally suited for this purpose. Other d-c recorders with a full-scale sensitivity of up to 200 microamperes with input resistance of 5000 ohms may also be used, with proper impedance matching. The RECORDER jack mating plug provided and a suitable two-conductor cable are used to interconnect the meter and recorder. The amplitude meter of the Model 308 is automatically switched out of the circuit when the mating plug is inserted in the RECORDER jack; positive d-c output voltage is applied to the tip (or center conductor) of the plug.

The full-scale d-c output (for any amplitude range) is one volt at 200 microamperes into a d-c impedance of 5000 ohms. D-C Recorder Part No. 9405 is furnished with Cable Part No. 9403. It requires no special matching and may be connected directly to the meter. Impedance matching requirements for other recorders should be such as to draw 200 microamperes into 5000 ohms at full-scale meter signal.

NOTE

Impedance matching errors will result in recorded amplitude errors.

If the recorder to be used has a variable sensitivity control, it may be calibrated by (1) applying a constant vibration to the pickup or a constant sound pressure level to the microphone, (2) observing the resulting meter reading, and (3) connecting the recorder and adjusting the amplitude for the previously observed meter value.

NOTE

- When making sound level recordings to determine maximum personnel exposure levels occurring over a given time period, use of 90 dB or higher ranges is recommended since recorded levels which exceed 90 dB(A) are of primary interest.
- For vibration recordings, use the amplitude range which will include the maximum vibration amplitude anticipated.

UTILIZING ANALYZER OUTPUT

The ANALYZER output is primarily intended to permit frequency analysis of sound level measurements, using a Mechanalysis Model 330, 340 or 350 Vibration Analyzer/Dynamic Balancer. The output may also be used for oscilloscope observation, when using either vibration or sound level measurement modes. (A suitable mating connector for scope interconnection is IRD Mechanalysis Part No. 4366 or ITT Cannon MS3106E-10SL-4S, or the equivalent.) The output signal is an a-c voltage proportional to the meter reading. The full-scale a-c output (for any amplitude range) is 764 millivolts (301 millivolts, Model 308M) rms into an impedance of 100K ohms.

Use of the ANALYZER output for frequency analysis of vibration measurements would be redundant; that is, if vibration frequency analysis (or balancing with phase readout) is desired, simply connect the vibration pickup directly to the Analyzer/Balancer instrument.

For frequency analysis of sound level measurements proceed as follows:

1. The C network on the Model 308 should be selected for all analysis work. (The purpose of analysis is to detect all frequencies contributing to the noise. This purpose will be defeated if the A or B network is selected, since lower frequencies may be attenuated to the point where they cannot be detected.)

2. Connect Analyzer pickup cable to Model 308 ANALYZER connector and to Analyzer PICKUP connector.

3. On the analyzer, set the DISP/VEL selector to "VEL" and the amplitude range selector to 1. (On metric units, set amplitude selector to 10.)

4. Adjust the Model 308 range selector for a meter reading on the dB scale.

5. Apply power to the analyzer and analyze the input signal in the same manner as for vibration frequency analysis. (Refer to analyzer operation manual for details.)

6. The amplitude of the frequency component that is "tuned in" is equal to the sum of the dB range switch setting on the Model 308 plus the dB meter reading on the analyzer.

If this amplitude is too small to read on the analyzer meter, the analyzer amplitude range switch should be switched to a lower scale. Each step is equivalent to subtracting 10 dB from the dB shown on the Model 308 range switch. (Do not reduce analyzer switch more than 2 steps, that is, 20 dB. Filter overloading may occur and erroneous readings obtained.) The dB sound pressure level of the "tuned in" frequency is equal to the sum of the Model 308 dB setting minus 10 dB for each analyzer step change plus dB reading on the analyzer meter.

For example, if the Model 308 is set to 60 dB, and the analyzer to .3 (for metric units, the analyzer range switch would be set at 3), and the analyzer meter reads +9 dB, the sound pressure level of the "tuned in" frequency is $60 \text{ dB} - 10 \text{ dB} + 9 \text{ dB}$ or 59 dB. See Figure 5A.

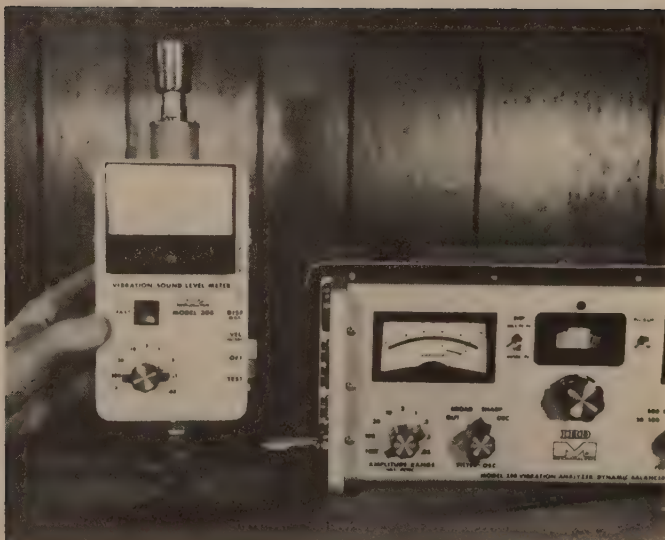


Figure 5A. The filtered sound pressure level component reading is +59 dB. It is the sum of the Model 308 and 350 amplitude range selector settings and the Model 350 amplitude meter readings +60 dB, -10 dB and +9 dB respectively.

VIBRATION MEASUREMENT TECHNIQUES AND APPLICATIONS

APPLYING THE PICKUP

Meaningful and accurate machinery vibration readings require reasonable care in selecting the points (on the machine) to be measured, and proper application of the pickup to those points.

The most significant measurement points will usually be at the bearings which support the major rotating component(s), or on solid machine structure as near the bearings as possible. These points are the best "transmitters" of the machine's vibration.

At a given measurement point (or bearing) on the machine, three "standard" measurement positions of the pickup may be used. These positions - "Axial," "Vertical" and "Horizontal" - are illustrated in figure 6. (For data-recording purposes the positions are abbreviated "A," "V" and "H.") The three measurements, when compared with each other and/or with their previous values, can provide important clues as to type or magnitude of possible problems.

Methods for applying the pickup are listed below. Factors which may affect the accuracy (or desirability) of these methods are given immediately after the list, and should be studied carefully.

1. Hand held, with pickup end cap directly against vibrating part.
2. Hand held, with pickup probe against vibrating part, as shown in figure 6.

3. Attached to machine with vise grip holder or magnetic holder (optional pickup accessories) as shown in figure 7.

4. Installed on 1/4-28 stud welded on or threaded to machine part. See figure 7. (Mounting surface must be flat and stud square with surface to ensure good readings.)

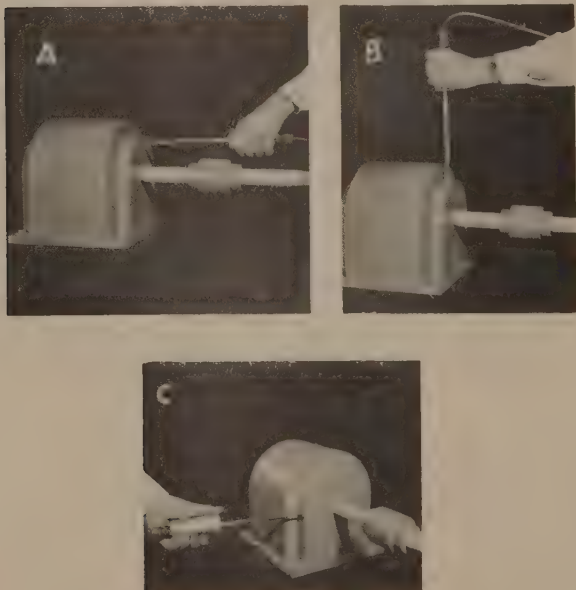
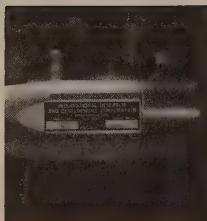


Figure 6. "Standard" Pickup Positioning



Vise Grip Holder



Magnetic Holder



Mounted on Stud

Figure 7. Applying Pickup for "Hands-free" Measurements

When hand-holding the pickup (with or without probe installed) use just enough force to prevent any chattering between the part and the pickup (or probe) - don't "lean" against the pickup. Keep the pickup as steady as possible while taking the meter reading.

Repeat measurements of a given point are taken to show any change in machine condition, by comparing the measurement values. When taking repeat measurements it is important to use the same relative pickup position each time, since a change in relative position can cause a change in the comparative measurements. To ensure "repeatability" when using methods 1, 2 or 3, make a practice of always placing the pickup in a reasonably true horizontal or vertical plane when conditions permit. If machine structure forces you to use an "unusual" pickup position, be sure to repeat that position for later measurements at the same point.

Methods 1 and 4 (hand held without probe, or stud mounted) may be used on machines or major machine components which operate at speeds of 720 to 60,000 RPM. The following methods are recommended only within the speed limits shown (due to "resonance" limits of the pickup accessories).

APPLICATION METHOD

SPEED LIMITS

Attached with vise grip
holder

720 to 8,700 RPM

Hand held, with 9" probe

720 to 16,000 RPM

Attached with magnetic
holder

720 to 37,000 RPM

MEASURING DISPLACEMENT

Vibration can be measured in terms of how far the part moves back and forth. This is called the peak-to-peak displacement or simply the displacement. The Model 308 measures this displacement in mils (or microns, Model 308M).

(1 mil = 0.001 inch; 1 micron = 1×10^{-6} meter.)

MEASURING VELOCITY

The Model 308 can also measure the vibration in terms of how fast the part moves. This is called the peak velocity and is measured in inches per second (or millimeters per second, Model 308M). Because velocity is a function of both displacement and frequency, it provides an added sensitivity to high frequency vibrations.

For instance, a vibration displacement of 0.1 mil (2.54 microns) results in the same meter reading when the frequency is 1800 CPM as it does at 18,000 CPM. The velocity for 0.1 mil at 1800 CPM is 0.0094 in/sec (0.239 mm/sec) but at 18,000 CPM the velocity is ten times as large or 0.094 in/sec (2.39 mm/sec). This means that small vibrations occurring at high frequency are easier to detect if velocity measurements are used. Since troubles such as bad bearings and gears cause vibration at high frequency, velocity measurements are extremely valuable.

VIBRATION TOLERANCES

Vibration measurements without a standard for comparison are seldom of any use. There must be some guide for determining how much is too much. Figure 8 provides a guide for Machine Tool vibrations.

TYPE OF MACHINE	Displacement of vibrations as read with pickup on spindle bearing housing in the direction of cut.		
Grinders	Tolerance Range		*
Thread Grinder	.01	—	.06 mils
Profile or Contour Grinder	.03	—	.08 mils
Cylindrical Grinder	.03	—	.10 mils
Surface Grinder (vertical reading)	.03	—	.2 mils
Gardner or Besly Type	.05	—	.3 mils
Centerless	.04	—	.1 mil
Boring Machine	.04	—	.1 mil
Lathe	.2	—	1.0 mils
#192 A	*	1 mil = 25.4 microns	

Figure 8. Guide to Machine Tool Tolerances

If machine tools vibrate beyond certain limits, the size or finish of the parts being machined will be unsatisfactory. The values listed indicate the range in which satisfactory parts have been produced. Actual tolerances must be determined by your own experience as to what vibration levels permit meeting size and finish tolerances.

For general types of machinery, the chart shown in figure 9 (or figure 10 if using Model 308M) may be used as a relative guide to how severe the vibration is. Of course, machine condition is considered to be progressively worse as severity increases from "Extremely Smooth" to "Very Rough." To interpret the severity when the machine vibration is measured in terms of displacement, the dominant (or principal) frequency of the vibration must be known. However, if the measurement is taken in terms of velocity, the severity can be read directly from the chart without knowing the dominant frequency. For example, a velocity reading of 0.1 in/sec (2.54 mm/sec) would indicate the severity (or condition) to be "Fair," regardless of the dominant frequency.

DETERMINING DOMINANT FREQUENCY

The Model 308 reads "overall" vibration. That is, if several vibrations (i.e., one at 1000 CPM, another at 2000 CPM, etc.) are present at the point being measured the meter reads the vector sum of all the vibrations. Usually one of these will be stronger (i.e., have more amplitude). This is the dominant vibration; knowing its frequency (or CPM) can tell us different things about the machine.

GENERAL MACHINERY VIBRATION SEVERITY CHART

For use as a GUIDE in judging vibration as a warning of impending trouble.

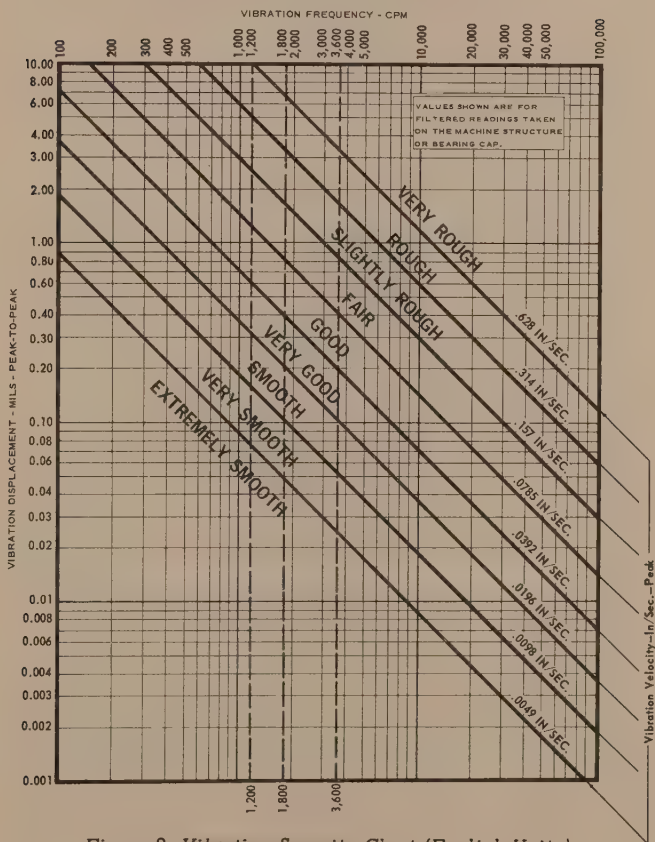


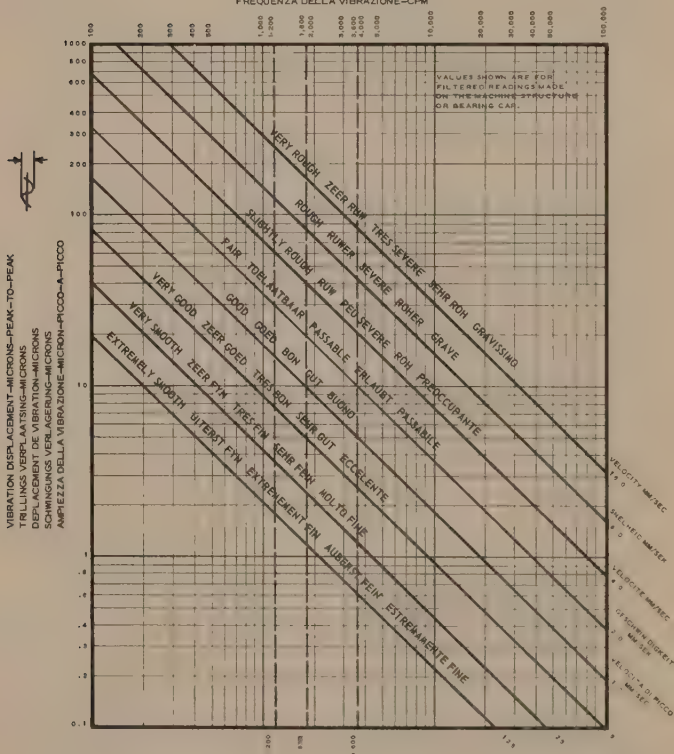
Figure 9. Vibration Severity Chart (English Units)



IRD-MECHANALYSIS INTERNATIONAL

GENERAL MACHINERY VIBRATION SEVERITY CHART
 TRILLINGS STRENGHEIDSKAART VOOR ALGEMENE MACHINES
 TABLEAU DE SEVERITE VIBRATOIRE POUR LES MACHINES EN GENERAL
 SCHWINGUNGSSTRENGE TABELLE FÜR ALLGEMEINE MASCHINEN
 NOMOGRAMMA GENERALE DI PERICOLOSITA DELLA VIBRAZIONE

VIBRATION FREQUENCY—CPM
 TRILLINGS FREKVENTIE—CPM
 LES FREQUENCES DE VIBRATION—CPM
 SCHWINGUNG FREQUENZEN—CPM
 FREQUENZA DELLA VIBRAZIONE—CPM



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The dominant frequency can be determined by taking both a velocity reading and a displacement reading at the same point with the Model 308 and then using the formula or chart solution described below.

CAUTION

- Although this method is in many cases a useful technique, use of a Vibration Analyzer is the preferred method for determining the specific vibration frequencies present.
- The dominant frequency cannot be accurately determined unless (1) both the VEL and DISP readings taken are very steady (i.e., the meter pointer does not change more than $\pm 5\%$ from the average value observed) and (2) the relative position of the pickup is not changed when taking the two readings.

Figure 11 is the chart solution, and can only be used if displacement and velocity are both in English units, or are both converted to English units.

The formula solution is:

$$\text{DOMINANT FREQUENCY (CPM)} = \frac{V}{D} \times 19,120$$

where V is velocity in in/sec (mm/sec) and D is displacement in mils (microns).

(The chart in figure 11 can only be used if dis-

placement and velocity are in English units, and the actual dominant frequency is between 500 and 10,000 CPM.)

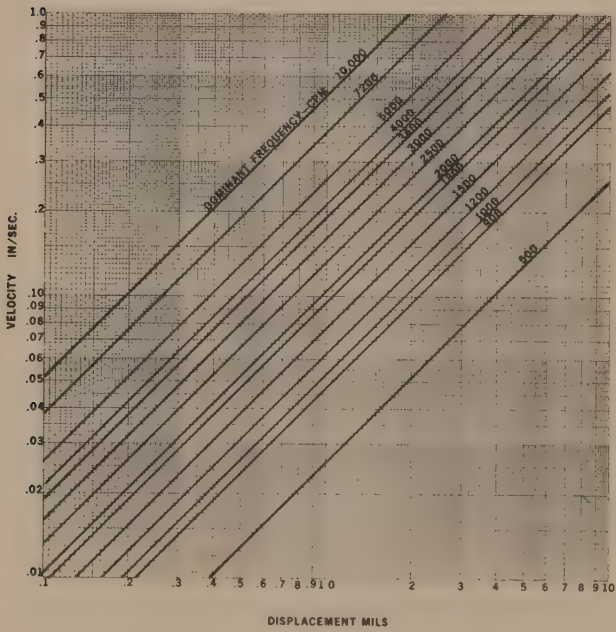
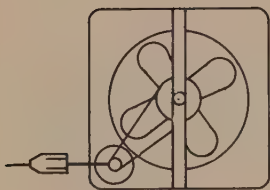


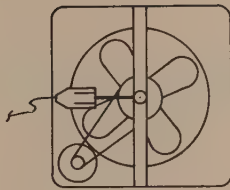
Figure 11. Chart for Determining Dominant Frequency

Significance of Dominant Frequency

Consider the belt-driven fan in figure 12. The motor and fan run at different speeds. The domi-



Measurements taken on motor contains vibrations of motor plus transmitted vibrations from the fan.



Measurements taken on fan contain vibrations of fan plus transmitted vibrations from the motor.

Figure 12. Transmission of Vibration

nant frequency will reveal which part of the machine is causing the most vibration. Measurements taken on the motor bearings would include vibrations of the motor plus vibrations from the fan transmitted through the drive belt and mounting structure. Conversely, measurements taken on the fan bearings would include vibrations of the fan plus vibrations transmitted from the motor. In many cases the point with the most vibration would pinpoint which part has the trouble, but not always. For example, structural design might cause the motor to vibrate more than the fan, even though the fan is the major cause of the vibration. To make a positive determination, the motor vibration is measured and found to have a displacement of $D = 1.85$ mils and a velocity of $V = 0.255$ inches per second. The dominant frequency is then calculated as:

$$\frac{0.255}{1.85} \times 19,120 = 2,649 \text{ CPM}$$

The motor and fan speeds are known to be 1,750 RPM and 2,600 RPM, respectively. From the calculation it can be concluded that the fan is the primary cause of the "overall" vibration measured at the motor. It can also be concluded that the cause of the fan vibration is probably unbalance, since unbalance of a rotating part causes a vibration frequency equal to its rotating speed. (It cannot, however, be concluded that only the fan is causing the vibration. After the fan is balanced, further measurements can indicate whether there is any significant trouble in the motor.)

Generally the dominant frequency will be equal to the rotating speed of the part causing the vibration, assuming that the trouble is unbalance. In any event the dominant vibration frequency will normally be some whole multiple of RPM of the part. After determining the dominant frequency, the type of trouble present may be assumed from the following:

DOMINANT
FREQUENCY

MOST LIKELY TROUBLES

1 x RPM

Unbalance and/or misalignment. If axial measurement value is 1/2 the value of the horizontal or vertical measurement, or larger, check for bent shaft or misalignment of couplings or bearings.

2 x RPM

Loose mounting or misalignment.

Use axial measurement to isolate, as stated above.

Many Times RPM Bad gears or bad roller or ball bearings.

There are many other causes of vibration not listed. To pinpoint all but the simplest requires a thorough analysis of the vibration using a Mechanalysis Vibration Analyzer.

VIBRATION MEASUREMENT APPLICATIONS

Preventive Maintenance

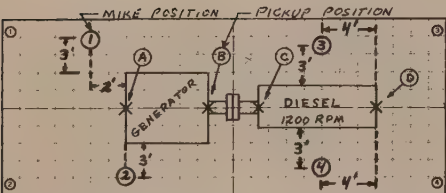
One of the most important applications of the Model 308 is making periodic vibration checks for preventive maintenance purposes.

The major phases of preventive maintenance are DETECTION, ANALYSIS, and CORRECTION. A measurable increase in the vibration of a machine is a symptom of wear or mechanical trouble. Periodic vibration measurements, recorded on a suitable data sheet such as shown in figure 13, provide the early DETECTION needed. Due to battery operation, size and simplicity of operation, the Model 308 is ideally suited for the DETECTION phase. The ANALYSIS phase pinpoints the cause of the trouble. Accurate vibration analysis requires the use of a Mechanalysis Vibration Analyzer/Dynamic Balancer. Once the problem is analyzed, CORRECTION can be scheduled for a convenient time; if unbalance is the problem, precise balancing can be achieved with the Analyzer/Balancer.

A primary requirement in setting up a preventive maintenance program is to initially establish the mechanical condition of each machine in the program. Although thorough measurements with the Model 308 can be of value, a true vibration analysis is best accomplished with an Analyzer/Balancer.

Note that the data sheet shown in figure 13 also includes provisions for recording periodic noise measurements. Noise measurements taken with the Model 308 can play an equally important role in

MECHANALYSIS PMP DATA SHEET



MACHINE: #2 SSDG

Component: DIESEL GENERATOR

Location: ENGINE ROOM

VIBRATION TOLERANCES

☐ DISP. ☒ VEL.

NOISE TOLERANCES

(A)BP

QUADRANT—

A 0.157 D 0.314

B Q. 157 E —

C O. 314 F. —

① 90 LBA

90 "

99 "

③ $\frac{90}{100}$

④ 90

[illegible]

preventive maintenance; additional details are given in the next section.

Balancing

In-place balancing is a routine procedure accomplished quickly and accurately with any Mechanalysis Vibration Analyzer/Dynamic Balancer. With its tunable filter rejecting all other vibrations, only the one from unbalance is shown on the amplitude meter; simultaneously the strob light fires on the component part to visually pinpoint the location of unbalance.

When a Mechanalysis Vibration Analyzer is not available or it's impossible to use a strob light, the Model 308 can be used for single-plane balancing under the following conditions:

UNBALANCE MUST BE THE MAIN CAUSE OF VIBRATION. Check to see if other causes of vibration such as misalignment of couplings or bearings, bent shaft, bad antifriction bearings, bad gears, mechanical looseness, etc. are present.

VIBRATION MEASUREMENTS MUST BE STEADY. The meter pointer must not fluctuate or slowly drift up or down scale more than about 10% of full scale.

THE DOMINANT FREQUENCY OF VIBRATION MUST BE THE SAME AS THE RPM OF THE PART BEING BALANCED.

If all three of the above conditions can be satisfied, use the following procedure for single-plane balancing.*

1. With the pickup, survey the part to be balanced for a point of maximum amplitude.

2. Attach the pickup at the point of maximum amplitude, using one of the methods shown in figure 7 if possible. (If the pickup is hand held make sure it is applied at the same point and in the same direction for all readings.)

3. Measure and record the original unbalance vibration. Call this reading 0.

4. Choose a trial weight. Carefully weigh and record the trial weight (TW).

5. Add the trial weight at any location on the part to be balanced and run the machine. Measure and record the vibration. Call this reading T_1 .

6. Move the trial weight to a location exactly 180° from the first spot and at the same radius. Run the machine. Measure and record the vibration. Call this reading T_2 .

* The procedure may also be used for two-plane balancing if necessary. Determine the plane (or rotor end) having the maximum vibration level and follow all steps to balance. Repeat the procedure for the second plane (other rotor end). Due to "cross effect" between planes, it may be found necessary to re-balance the first plane to achieve a good final balance.

7. With the above data, the amount of weight and the angular position necessary to balance the part may be determined. A sheet of paper, a ruler, protractor and compass are required.

8. Draw a circle with a radius equal to the original unbalance (O). The radius represents the original unbalance vector in MILS. A scale of one-half inch equals one mil is suggested. Then, draw a line vertically through the center of the circle that intersects the circle. The intersection at the top is point A, at the bottom, point B. See figure 14 Step A.

9. Using the same scale, draw an arc with a radius equal to the vibration reading T_1 . The center of the arc is at point A. See figure 14 Step B.

10. Using the same scale, draw an arc with a radius equal to the vibration reading T_2 . The center of the arc is at point B. See figure 14 Step C. Note that arcs T_1 and T_2 intersect in two places.

11. Draw a line from the center of the circle to one of the intersections of the two arcs. Using the same scale measure the length of this line in mils. Call this value R. See figure 14 Step D.

12. To determine the correct weight to balance the part, multiply original unbalance (O) in MILS by trial weight (TW) and divide by the resultant (R) in MILS.

$$\text{Balance Weight} = \frac{O \times TW}{R}$$

13. To determine the angular location for the balance weight, measure with a protractor the angle between line A-B and line R. Call this angle M. See figure 14 Step E.

NOTE

The actual spot to attach the balance weight is either clockwise or counterclockwise by an angle equal to the measured angle M, from the spot where the trial weight was added for reading T_1 .

14. Place the balance weight calculated in step 12 on the part at the measured angle M clockwise from the spot where the trial weight was first added to obtain reading T. If the vibration reading is not acceptable move the weight to a spot M degrees counterclockwise from the spot where the trial weight was added to obtain T_1 .

Incoming Inspection

Vibration tolerances are often included in specifications of purchased components to prevent excess vibration in finished products. The Model 308 is ideal for inspection in receiving or on the assembly line.

Field Service

Field engineers and service men can quickly determine if vibration is the justifiable cause of a customer complaint. The portable Model 308 is easily carried to the job.

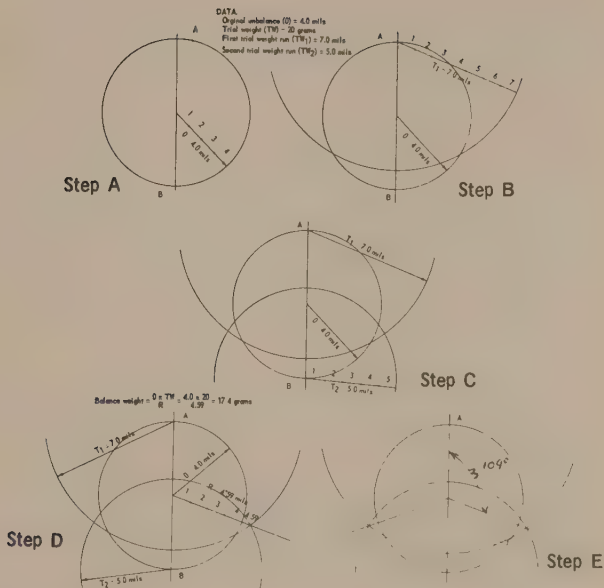


Figure 14. Step-by-step Balancing, Vector Diagram Construction

Final Assembly Testing; Installation Checkout

Final vibration checks of finished products and assemblies before shipment assures compliance with production quality standards and thus improves

customer satisfaction. New or overhauled machines can be checked for vibration from troubles due to faulty installation.

SOUND LEVEL MEASUREMENT TECHNIQUES AND APPLICATIONS

SOME FUNDAMENTALS OF SOUND AND NOISE

Basic Characteristics of Sound

Defined in technical terms, sound is a pressure oscillation in a fluid (water, air, etc.), which moves radially away from the source which produces it. Sound radiates by, or is "propagated" by, wave motion through the fluid or "medium." The four characteristics of this wave motion are amplitude, frequency, velocity and wavelength.

The velocity of sound is essentially "fixed" by the medium in which it travels; e.g., in air, 1100 feet per second; in water, 4800 feet per second. (Velocity changes somewhat with temperature or pressure changes of the medium.) The wavelength (λ) is the distance between similar points on two adjacent "waves," and is determined both by the velocity (c) and the frequency (F) at which the waves are propagated, or:

$$\lambda \text{ (feet/cycle)} = \frac{c}{F} \frac{\text{(feet/sec)}}{\text{(cycles/sec)}}$$

The frequency of sound is determined by the source causing it. One of the most common sources of sound is a vibrating solid (see figure 15). The vibrating or oscillating motion of the solid causes pressure changes (or oscillations) in the surrounding air, and hence the pressure oscillation (or sound) frequency is the same as the vibration frequency of the solid. If a number of individual

components of the machine shown in figure 15 are each vibrating at a different frequency, the "overall" sound radiating from the machine will contain an equal number of individual "pressure oscillation" (or sound) frequencies.

The amplitude of sound is determined by how much the medium is alternately compressed and rarefied during the pressure oscillations caused by the source. Stated in another way, the amplitude is a measure of the energy imparted to the medium by the source. The initial energy imparted to the medium dissipates with distance; hence, at any given point away from the source the amplitude is also a measure of the energy which can be imparted by the medium to a "receiver" (such as a microphone, or our ear).

Sound amplitude is measured with an instrument (or sensed by our ear) in terms of the pressure level changes (relative to the average or "atmospheric" pressure of the medium) that take place during the pressure oscillations. Hence, "sound amplitude" is more commonly called "Sound Pressure Level" (abbreviated SPL).

In addition to "sound pressure level," the term "sound level" is also commonly used in place of "sound amplitude." If sound is measured with an instrument that is fully responsive to all frequencies of sound, then the measured value will be in terms of "sound pressure level" - that is, it will measure what is actually "out there," or the true sound pressure level. For reasons explained later (see "How the Ear Hears") it is also desirable to measure sound with instruments designed to be fully responsive to some frequencies but less

responsive to others. Such instruments are usually called Sound Level Meters, and readings obtained with them are (or should be) called "sound level" readings; that is, they are not meant to measure in terms of actual "sound pressure level."

What is Noise?

The generally accepted definition of noise is simply "unwanted sound." This includes everything from the drip of a faucet in the middle of the night to the mighty roar of a moon rocket as it leaves the launch pad. It can even include music, if it interrupts the work of the listener. To be considered "noise," all that is required is that it be sound that is undesirable to the listener. In fact, in all of the preceding (or following) text, the word "noise" could be used to replace "sound" as long as the definition just given is applicable.

How Sound (or Noise) is Generated

Sound or noise can be generated in three ways. The most common of these is the vibrations of solid structures such as machines or wall panels which alternately compress and rarefy the air in contact with these structures. See figure 15. The rate or frequency at which these structures vibrate determines the frequency of the sound which is radiated. Thus, a 100 Hz (6000 cpm) vibration will generate a 100 Hz (6000 cpm) sound wave.

Sounds can also be generated by the movement of air over solid structures. A typical example is shown in figure 16. Even though the structure

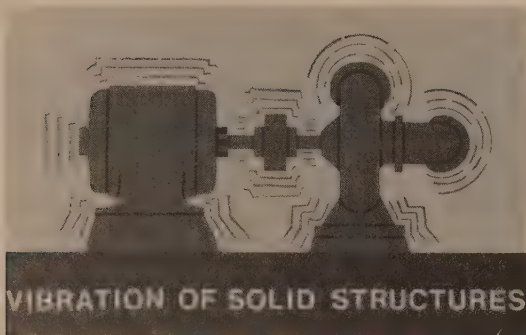


Figure 15. Most Common Source of Noise

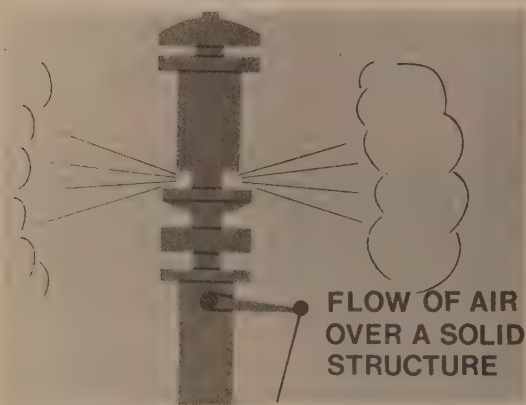


Figure 16. Air Moving Over Solid Structure Generates Noise

itself does not vibrate, the moving air can still create loud sounds. The most well-known example of this is the pipe organ. The flow of air over fan blades, or through ventilation grills, are other examples.

The third mechanism of sound generation comes from the turbulent mixing of fast moving air with relatively slow moving air in which no solid structures are involved. An example of this which is commonly heard is the noise from a jet engine. See figure 17. This type of sound only becomes important when the air (or gas) is moving at very high velocity.

All three of these sound generating mechanisms are commonly found in many types of industrial machinery; and by recognizing them, it is often possible to reduce them to acceptable levels.



Figure 17. Fast-moving Air Mixed With Slow-moving Air Generates Noise

The Decibel

Sound, or noise, is measured in units called "decibels," which are abbreviated "dB." They are as easy to use as mils, microns, inches, or millimeters once you get a feel for them. The levels of a number of commonplace sources of noise are given in following paragraphs to provide this "feel."

From a technical standpoint, the decibel was selected because of the tremendous range of sound levels which the human ear can hear. Sound pressure levels of interest for engineering purposes cover a ratio of one billion to one ($10^9:1$). This made it very inconvenient to handle with conventional linear units such as lb./in.² (psi) or microbars. The decibel provides a logarithmic scale which compresses that huge linear range of one billion to one ($10^9:1$) into a decibel (logarithmic) range of only 180 to one (180:1).

Although it is not necessary to the understanding and measurement of noise, for those interested, sound pressure level is defined by the following equation:

Sound Pressure Level = SPL

$$\text{SPL} = 20 \log_{10} \frac{\text{Measured Sound Pressure (microbar)}}{\text{Reference Sound Pressure (microbar)}}$$

where Reference Sound Pressure = .0002 microbar (or 20 micronewtons per square meter).

Common Noise Sources and Levels

Figure 18 shows representative decibel levels encountered by people during the course of a day from common noise sources other than industrial.

Of course, these are only given as typical levels. Each of these sources can vary over a wide range depending upon a number of factors such as changing conditions at the "typical" source, the distance one is from the source, and the presence or absence of solid flat structures or surfaces which reflect the noise.

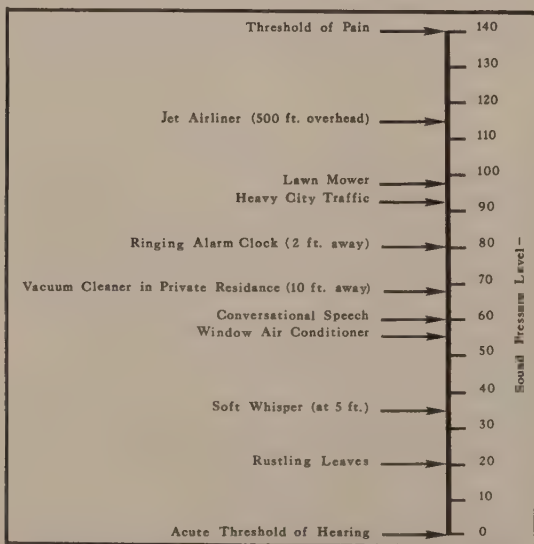


Figure 18. Common Non-Industrial Noise Levels

Industrial Noise

Noise generated by industry may be divided into two classes: those sources which affect the community around the industrial site, and those that affect the personnel on the site.

Large I. D. Fans, large transformers and high-pressure steam breakdown are examples of sources which can cause community noise problems. Diesel engines, compressors, chippers and grinders are a few of the sources which can affect personnel efficiency within a plant. Figure 19 provides examples of noise levels from industrial sources.

Acceptable Noise Levels for Different Working Areas

Numerous experimental studies have shown that workers' efficiency can be affected in varying degrees by noise. Tasks requiring a great deal of mental concentration and exactness are affected by noise to a significantly greater degree than others. For instance, even relatively moderate noises tend to dilate the pupils of the eyes, which results in a change in the eyes' focus. Thus, a watchmaker, and others who do close work, will experience difficulty in working where periodic loud noise is present.

In many cases the ability to verbally communicate is the governing criterion for acceptable noise levels. Here again, there is some variability; levels required for a conference room will differ from those required in a machine shop, or in the engine room of a ship.

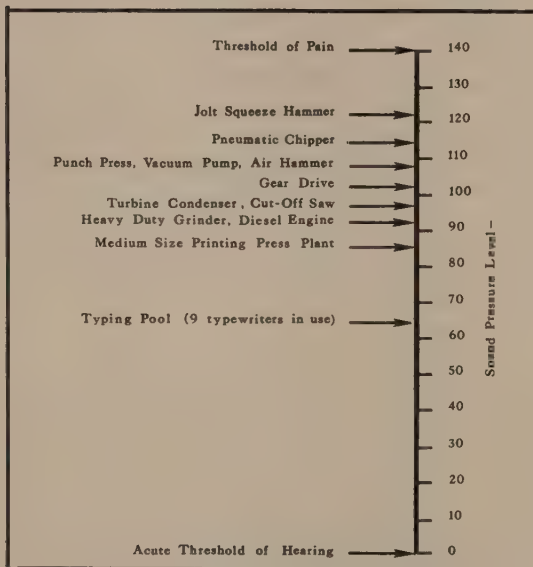


Figure 19. Typical Industrial Noise Levels

Where high noise levels occur in areas where work is less exacting and more routine, acceptability levels are governed by noise which can cause personnel fatigue and inefficiency. Figure 20 indicates some general guidelines on levels of acceptability for noise in different areas and conditions.

NOISE LEVEL dB(A)	COMMUNICATION REQUIREMENTS	TYPICAL ACTIVITY OR WORKING AREA
110	Communication nearly impossible. Maximum shouting required at a distance of one foot or less	
100	Shouting required: Communication difficult even at one foot dis- tance	
90	Shouting required at one foot. Max- imum level at which telephone can be used	
85	Raised voice can be understood at two feet	All working areas: For most tasks, worker efficiency is affected above this level
70	Telephone use not a problem up to this level. Normal voice can be understood at three foot distance	Machine shop, restaurants, busy department store
65		Secretarial offices
55	Normal voice can be understood at 12 foot distance	Conference room, class room
50		Private office, drafting room, where close exacting work is required.
30		Broadcast studio

Figure 20. Guidelines for Acceptable Noise Levels

How the Ear Hears

The ear is a remarkable "sound instrument" in that it functions over an extremely wide range of amplitudes and frequencies, can detect very small changes or differences in amplitude and frequency, and with experience can even do a good job of "judging" the actual frequency (or "tone") of a specific sound.

In judging "loudness," however, the ear tends to respond poorly to sounds having frequencies near the low and high ends of a range of 20 to 10,000 Hz. This is particularly so at the lower end, i.e., from about 200 Hz down to 20 Hz. Sounds having frequencies between the range of 200 to 6000 Hz are "heard" essentially as their actual levels (or may even be amplified slightly)

Still another factor in this "poor response" characteristic of the ear is that as sound pressure level increases the response improves. For example, at 20 Hz an 80-dB SPL will be "heard" as a "20-dB sound" (a response error of 60 dB), whereas a 130-dB SPL will be heard as a 100-dB sound (an error of only 30 dB).

A, B and C Weighting Networks

Since sound is often measured in conjunction with a problem related to human hearing, it has been found desirable in many cases to use instrumentation which measures sound in a manner similar to the human ear. To do this, sound level meters such as the Model 308 are electronically designed to "hear" poorly at low and high frequencies, and "hear" best around 4,000 Hz (240,000 cpm). The response "curves" of the Model 308 to sound of different frequency, depending on the A, B or C mode selected, are shown in figure 21. The electronics which generate this type of response are correspondingly called the A, B and C "weighting networks."

As mentioned previously, the ear responds differently to sounds of different levels. Thus, for low-level sounds (below 55 dB), the A weighting

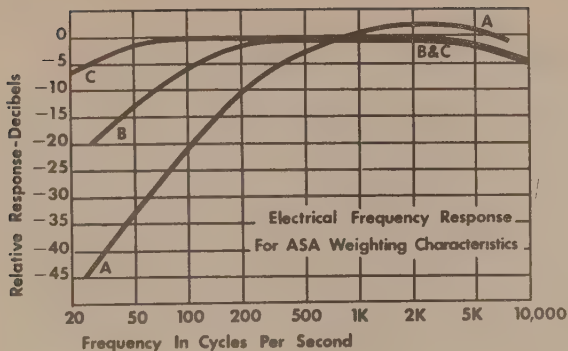


Figure 21. A, B and C Weighting Networks Response Curves

best approximates the human ear; from 55 to 85 dB the C weighting. For data recording it is necessary to specify what weighting is being used. For example, the sound levels are recorded: 50 dB(A), or 75 dB(B), or 92 dB(C), etc.

In many cases, to simplify the measurement and recording of the measured sound, standards have been set which call for measurement using a specific weighting network regardless of the level of the sound. Perhaps the most prominent example of this is the Walsh-Healey Public Contacts Act, which states that sound shall be measured in dB(A) sound level.

SOUND LEVEL MEASUREMENTS

Relative Positions of the Meter and Operator

The meter should be held in an approximately level attitude, keeping the microphone pointed directly away from the body. It may be held with the carrying strap (with the hands free for recording data)

as shown in figure 3 (in Description section), or it may be hand held directly in front of the body and extended somewhat. Initially, the operator should stand so that the microphone axis will be pointing 90° from an imaginary line between the meter and apparent source. (Again, see figure 3.) Without moving forward or back, the operator can then pivot slightly left and right to note any possible change in the meter reading, taking the highest value at that position.

Initially the operator cannot readily assume from which direction the sound is arriving. (It may be from the "obvious" source, from a reflecting surface, or both.) Because of this the operator should always keep the meter squarely in front of him, and should keep his hands (or data-sheet clipboard) well clear of the microphone. Not to do so might interrupt the sound path or reflect the sound, in either case affecting the reading.

The height of the meter above the floor must also be considered. Using the carrying strap will maintain a constant height when taking a series of readings. However, this may not be the proper height; measurement requirements may call for some other height, or it may be found that a significantly higher noise level is read if the meter is raised a foot or so from waist level. Usually the important consideration is finding the height where the maximum reading is obtained, with the microphone pointed away from the body and the source to the left or right.

Measuring Machinery Noise

The positions selected for measurement of machinery

noise depend upon the purpose of the measurement. For example, some government regulations require measurements at positions which will be representative of locations of workers' ears, since their purpose is to control the amount of noise to which workers are exposed. Other standards require measurement at a number of fixed positions (e.g. 3 ft. from machine surface, on each side of machine at the height of its centerline, and at the mid-length of the machine). Such measurements are generally made by machinery manufacturers to permit estimation of the noise a machine will make when placed in different surroundings. Still other standards require measurement positions at which the sound pressure level is the highest in order to estimate whether the machine will be a community noise problem.

From the standpoint of the measurement of industrial noise, where the objective is compliance with the government regulations and other similar hearing conservation standards, a good approach is as follows:

1. Sketch an overhead or "top" view of the machinery configuration to be measured, on a form such as the Mechanalysis PMP Data Sheet (Form No. 278A). (This same form is used for periodic vibration checks.) See figure 22. Note that the region around the machine is divided into four quadrants (1,2,3,4) at the coupling between the driver and driven unit. One sound measurement is to be made in each quadrant.

2. The machine is checked to determine that it is operating at its standard condition (temperature pressure, flow, load, speed, etc.) and these condi-

A detailed layout diagram of the generator and pickup assembly. The diagram shows a rectangular area divided into sections by dashed lines. Key components and dimensions include:

- GENERATOR:** A rectangular component on the left, labeled "GENERATOR". It has a width of 2' and a height of 3'. It is connected to a pickup assembly.
- PICKUP POSITION:** A rectangular component on the right, labeled "PICKUP POSITION". It has a width of 4' and a height of 3'. It is connected to the generator.
- DIODES:** Two diodes are shown, labeled "DIODE" and "DIODE 1200 RPM". They are connected to the pickup position.
- Dimensions:** The overall width of the assembly is 4'. The overall height is 3'. The distance between the generator and the pickup position is 2'. The distance between the pickup position and the diodes is 4'.
- Labels:** "MIKE POSITION" and "PICKUP POSITION" are labeled at the top. "GENERATOR" and "DIODE 1200 RPM" are labeled on the components.
- Connections:** Arrows indicate the flow of signal or power from the generator to the pickup position and then to the diodes.

MACHINE: # 2 SSDG

Component: DIESEL GENERATOR

Location: ENGINE ROOM

VIBRATION TOLERANCES

☐ DISP. ☒ VEL.

A 0.157 D 0.314

B 0.157 E —

C 0.314 F —

NOISE TOLERANCES

dB(A)

QUADRANT—

① 90 18A

② 90 "

③ 90 "

④ 90 "

[illegible]

tions noted on the PMP data sheet.

62

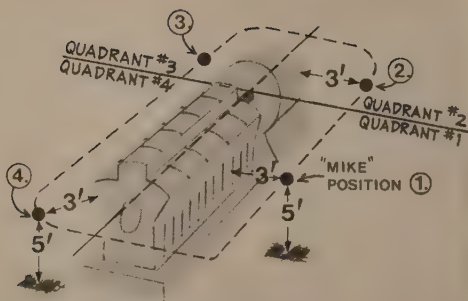
4. The microphone (i.e., the meter/microphone combination) is positioned in quadrant 1 by locating it 5 ft. above the floor and 3 ft. from the machine surface. The microphone is then moved slowly along the machine at this 5-ft. height and 3-ft. distance until the position of highest sound level in the quadrant is determined.

5. The microphone is moved around within an approximate one cubic foot volume at this position, and the variation in sound level noted. If this variation is 3 dB or less, then this position is satisfactory. If variations are greater than 3 dB, the microphone should be moved (for example) to a distance of 5 ft. from the machine, and the position of highest sound level re-established.

6. A check must also be made to make sure that the microphone is more than 3 ft. from reflecting surfaces. Large flat structures such as walls cause the greatest reflections, but other surfaces such as large adjacent machines can also cause reflections. When the noise level increases as the microphone moves away from the noise source and toward a wall, this is a sign that the measurement should be made nearer the machine.

7. Once the measurement position has been established, it should be permanently located by a suitable mark on the floor, and by dimensioning the position on the PMP Data Sheet. See figure 23.

8. If, in addition to the above, there are operator stations near the machine, sound measurements should also be taken at these locations. The microphone should be located at the approximate position of the operator's ear. The machine



TYPICAL METHOD FOR ESTABLISHING MICROPHONE POSITIONS

Figure 23.

Establish Microphone Positions With Floor Marks and Data Sheet Diagram

operator should not be near the microphone when the measurement is taken. Such data should be appropriately identified on the data sheet and in the sketch.

Selecting A, B and C Networks

The selection of which network to use is generally governed by the standard under which the noise measurements are being made. For instance, the Walsh-Healey Act specifies that the "A" network will be used. If the degree to which communication is hindered by noise is of primary interest, again the "A" is used because it has been found to be a good measure of speech interference.

On the other hand, if the noise measurement is being made to track down an unknown (but annoying) source of machinery noise the "C" network is the better choice, since it does not discriminate against low frequencies.

Although the "B" network has not been used to a great extent in industrial applications, there may be cases where it is useful.

Measuring Background Noise

Sound measurements of a given machine are more frequently subject to interference from other sources than are vibration measurements. For this reason, it is desirable to make initial measurements both with and without the machine running. By comparing the levels under these two conditions, it is possible to determine the extent of the noise contribution from other sources when measuring the machine's noise. If the level with the machine running is 10 dB above the background level, there is essentially no interference from the other sources. At the other extreme, when the noise level doesn't change when the machine is turned on, then the other sources dominate. In this case, a valid measurement of the machine's noise can only be obtained if the other sources are shut down.

When the Noise Level Oscillates with Time

It is not uncommon to find that the measured noise level oscillates in amplitude. This can be caused by several conditions: 1) the source itself can be unsteady, 2) two sources with slightly different frequencies can be beating together, or 3) the path by which the noise reaches the microphone can be

varying. If the oscillation cannot be eliminated, the maximum and minimum measured levels are re-recorded.

To obtain a more accurate evaluation of changing or oscillating levels, the FAST response push-button on the meter may be used. Check the reading using both fast and slow response to see if there is any significant difference before deciding that fast response is necessary. Data taken in the FAST mode should be noted as such when recorded.

Measuring Impact Noise

Many noises in industry are not steady. These are the "clangs," "bangs" and "thuds" of forges, steam hammers and presses, rather than the steady "roar" and "rumble" of turbines, fans and compressors. Since impact noise affects human hearing differently from steady-state noise, it is important to be able to distinguish between the two. An "impact" is a single collision of one mass in motion with a second mass which may be either in motion or at rest. The Walsh-Healey Act defines impact noise as those sounds which have peak amplitudes at intervals greater than one second. Specifically, it states:

"If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous."

The Act further states that:

"Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level."

In measuring impact noise it should be noted that

the measurement must be in dB peak sound pressure level, not dB(A). "Peak" means the maximum overall amplitude of noise sound pressure. Thus, the dB(A) scale is not satisfactory, since it attenuates the amplitude of the low frequency noise.

Where many impact noise measurements are to be made, it is desirable to use a specialized instrument called an impact noise meter, or impact noise analyzer. For occasional impact noise measurements, however, reasonably good approximations can be obtained with the Model 308.

To make an approximation with the Model 308 the "C" mode or network is selected, the range selector is set at "120", and the FAST response pushbutton is held down. If the measured impact noise does not exceed 125 dB(C), then the impact is considered to be below 140 dB peak. This, however, is true only if the duration of the impact noise is greater than 5 milliseconds. If the impact duration is less than this, the actual impact level could exceed 140 dB peak. For this reason the impact noise meter is preferable.

Another method of impact noise measurement is to connect an oscilloscope to the ANALYZER output of the Model 308. Amplitude levels are scaled on the scope using a steady reference signal at various amplitudes such as 90, 100 and 110 dB. Impact noise amplitude is then noted on the scope by visual observation.

Frequency Analysis of Noise

When excessive noise is detected either because of personnel complaints, or because of routine period-

ic noise checks, the next step is to make a frequency analysis of the noise to determine its cause. To do this, the Model 308 is interconnected with a Mechanalysis Vibration Analyzer/Dynamic Balancer. (Refer to "Utilizing ANALYZER Output" in Operation section.) A typical setup is shown in figure 24. Note that the Model 308 microphone is placed so that it is perpendicular to the noise path, and the equipment is arranged so as not to interrupt the path. Also, the Model 308 is placed in a fixed position, rather than using the hands or carrying strap.

The analysis procedure (similar to that for vibration analysis) determines the major frequencies contributing to the overall noise. The frequencies detected will usually be equal to the machine rotating speed (i.e., 1 x RPM) and to whole multiples such as 2 x RPM or 3 x RPM, etc. If for example a 6-bladed fan were being analyzed, a predominant noise frequency of 6 x RPM would probably be detected. The primary goal, of course, is to be able to relate the major noise frequencies to specific machine components, thus pinpointing the primary source (or sources) of the noise. As stated in the Operation section, the C network should be used during all noise analyses, to avoid attenuation of lower frequencies.

After (or while) determining the major frequencies, the Analyzer/Balancer strob light can be a powerful tool in helping to pinpoint their mechanical source. The strob light flash frequency is tuned to the major frequencies detected. When the light is directed on various parts of the machine, the noisy part will appear "frozen."

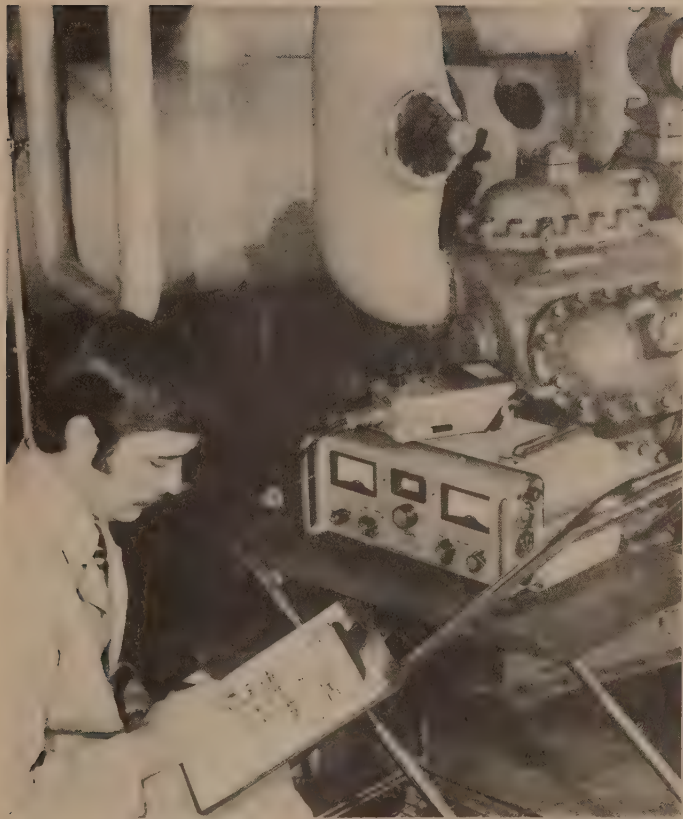


Figure 24. Typical Setup for Noise Analysis

The noise analysis can be performed independently, or in conjunction with a vibration analysis. The form shown in figure 25 is designed specifically for analysis data, and provides space for recording both noise and vibration amplitudes and frequencies.

IRD MECHANALYSIS, INC.			DATA SHEET		DATE <u>AUG. 23</u>						
☒ NOISE ☐ VIBRATION FOR: <u>PLANT ENG.</u>			ANALYSIS OF: <u>#4 COOLANT PUMP/MOTOR</u> TEST CONDITIONS:								
MECHANALYSIS EQUIPMENT USED: <u>MODEL 330 WITH</u> <u>SOUND ACCESSORY</u> PERFORMED BY: <u>J. R. T.</u>											
LEGEND: → PICKUP POINT X PLAIN BEARING □ ANTI-FRICTION BEARING — COUPLING											
PICKUP POINT	POS	NOISE		FILTER OUT		VELOCITY			FILTER IN		
		dB(A)	CPM	MILS	CPM	IN/SEC	CPM	1800	3600	7200	
Sound	1	79	~					75	-	76	
	2	82	~					72	-	80	
	3	84	~					72	-	82	
	4	81	~					76	-	75	
A	H					3/4 1800		3	06	01	
	V					20/25 ~		2	03	-	
	A					07/08 ~		05	03	-	
B	H					28/3 1800		25	03	01	
	V					15/19 ~		15	02	-	
	A					06/10 ~		07	03	-	
C	H					15/20 1800		14	03	02	
	V					12/15 ~		10	02	01	
	A					07/11 ~		07	03	01	
	H										
	V										
	A										
	H										
	V										
	A										
	H										
	V										
	A										

Figure 25. Typical Noise and Vibration Analysis Data Sheet

After analyzing and correcting the problems which exist, additional readings should be taken using the analysis setup, and the noise reduction obtained noted on the analysis data sheet. Overall reduction (as read on the Model 308) may be entered on the form used for periodic noise measurements. Retaining this data may be useful as documented evidence of an on-going Noise Control Program.

NOISE MEASUREMENT APPLICATIONS

Preventive Maintenance

Noise measurement and control is a logical extension of the machinery vibration preventive maintenance program because of the close relationship of noise to machinery mechanical condition. In the preceding sections, it was shown that the instruments, procedures, data records and personnel involved in the vibration preventive maintenance program can be utilized equally effectively for noise measurement and control. In fact, noise and vibration measurements, incorporated in a single preventive maintenance program, can provide mutual back-up data when made simultaneously. For example, when high vibration levels are detected and machine defects are subsequently corrected, noise measurements taken before and after correction can provide evidence of an effective noise control program. Alternately, an increase in noise levels may signal a vibration problem which was not detected by vibration measurements. Severe cavitation in a valve at a location removed from a machine is an example of such a problem. Thus, by combining the noise measurements with the vibration Preventive Maintenance Program, the program is strengthened, noise control established, and the man hours required to

work an effective program are minimized.

Integrating noise measurement in the vibration Preventive Maintenance Program is accomplished by following the same basic techniques used for the vibration program, and applying the appropriate measurement techniques given in this section.

Quality Control

The noise levels of new operating or production machinery, or purchased product components, can be checked against the manufacturer's specifications, or the specifications stipulated with the purchase order. Noise tests of finished products or assemblies will ensure compliance with internal quality control standards, or those specified by customers.

Field Service

The Model 308 provides the field engineer or serviceman with a three-fold approach for verifying whether or not customer complaints are justified. Both vibration and noise levels may be determined and related to alleged machine problems. Finally, noise data may be taken in the machine or installation area to demonstrate compliance with personnel exposure standards and safety requirements, community noise pollution restrictions, etc.

Personnel and Community Problems

Excessive plant noise, regardless of the source, creates a wide variety of administrative problems. These problems are highlighted in subsequent paragraphs. Initially, management must be aware of the problems that can exist due to excessive noise.

Assuming this awareness, sufficient data can in most cases be obtained with the Model 308 to determine whether or not the types of problems described exist, and if so to what extent. Correction of those problems that do exist will require one or more of the following courses of action, depending on their severity:

1. Quiet the source. The source will almost always be mechanical equipment. Correcting existing mechanical problems provides the dual benefit of lowered noise level and extended machine life. Beyond this, controls such as mufflers and acoustical enclosures or coverings, etc., may be considered, with machine redesign as a final alternative.

2. Isolate personnel from the source.

3. Limit exposure time of personnel.

4. Provide ear muffs or ear plugs to individuals in affected areas.

Personnel Efficiency

When noise levels in industrial areas are high, it becomes difficult to communicate. Orders must be given in as brief terms as possible, and discussion of problems is only barely possible. Further, the chance of misinterpretation of verbal information increases, and beyond a certain noise level, communication becomes impossible. In offices or precise-work areas as noise increases worker efficiency starts to decrease, since it becomes increasingly difficult for personnel to concentrate on their work.

To make an initial evaluation in a specific area, refer to the noise levels given for typical working areas, in figure 20. If measurements indicate higher levels, efficiency is most likely being affected.

Safety

The relationship of excessive noise to personnel safety can readily be appreciated. In excessive noise, unheard "safety" warnings such as a shouted "Stop!", the sound of an approaching vehicle, or the noise made by a change in a machine's condition may result in serious injury. Misinterpreted instructions may bring the same result. The key to this problem is an awareness of the various safety factors in a given area, such as amount of vehicular traffic, types of machines being controlled, and the need for accurate communication. Once the safety "problem possibilities" are identified safe noise limits to combat them may be established, and the area measured to determine if the limits are exceeded. The charts shown in figures 19 and 20 may be helpful in establishing the necessary limits. (The values in figure 20 are in dB(A), while the values in figure 19 are in SPL. To best approximate SPL values the C network should be used for comparative measurements.)

Community Noise Pollution

With increasing concern about pollution caused by industry, noise has received more than its share of attention. Community action against noise nuisances is becoming more frequent, and is receiving a more sympathetic hearing from the courts and the public. This clamp-down on noise will

continue and become more and more restrictive as new noise control laws are enacted.

To evaluate possible problems a noise survey around the immediate plant perimeter should be made, noting which areas have the highest levels, and their values.

An important factor to be considered is that the highest noise level measured at the plant will be heard at essentially the same level in the surrounding community when the noise is carried by wind. Hence, the direction of the prevailing wind and the nature (business, residential, population density, etc.) of the community area "downwind" will both relate to the severity of the problem.

Closing off or baffling the path from high-level sources to the outside may be considered if quieting the sources is impractical.

Hearing Damage

One of the major topics under the subject of Noise Control is "Hearing Damage." That this is true stems from the simple, well-proven fact that prolonged exposure to excessive noise will result in permanent hearing damage. The extent of possible damage can range from a slight reduction in hearing ability to total loss of hearing. Although the fact (and the contributing causes) have been with us throughout the Industrial Age, it is only in the recent past that enough knowledge on the problem has been obtained to deal with it effectively. As this knowledge emerged, so did regulations spelling out what must be done. Although such regulations have been initiated primarily at the

Federal level, State and Community agencies have enacted or are considering similar regulations.

The most important regulation of this type is contained in the Walsh-Healey Public Contracts Act under Section 50-204.10 (dated May 20 1969 and as revised July 15 1969). The importance of the regulation lies in (1) the definition of those manufacturers or organizations who must comply with the regulation and (2) the criteria set forth for protecting the hearing of personnel.

The subject Section of the Walsh-Healey Act states that any manufacturer who wishes to sell to the Federal Government goods valued in excess of \$10,000 or services valued over \$2,500 must take steps to protect his employees' hearing. The Occupational Safety and Health Act of 1970 now enforces Section 50-204.10 to apply to all organizations engaged in Interstate Commerce.

In regard to criteria set forth in the standard, the following is taken in part from the Federal Register, Vol. 34, No. 96 (dated as noted above).

50-204.10 Occupational
Noise Exposure.

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table I of this section when measured on the A scale of a standard sound level meter at slow response.

(b) When employees are subjected to sound exceeding those listed in

Table I of this section, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

(c) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

(d) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Table I
Permissible Noise Exposures¹

Duration per day, hours	Sound level dBA, slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

¹When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2 \dots C_n/T_n$ exceeds unity, then the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level.

The following example illustrates the use of the noise exposure equation given with Table I above:

Several Amplitude vs Time recordings of an eight-hour shift revealed that average personnel exposure levels and durations were 87 dB(A) for 5.6 hours; 97 dB(A) for 2 hours; 110 dB(A) for 18 minutes (0.3 hour); and 115 dB(A) for 6 minutes (0.1 hour). The 87-dB(A) level is disregarded because it is less than the 90 dB(A) level where exposure duration must be considered. From this data, $C_1 = 2$ hours and the allowable exposure at 97 dB(A) is 3 hours, or $T_1 = 3$; $C_2 = 0.3$ hours and $T_2 = 0.5$ hours; $C_3 = 0.1$ hours and $T_3 = 0.25$ hours. Then:

$$\frac{2}{3} + \frac{0.3}{0.5} + \frac{0.10}{0.25} = \frac{2}{3} + \frac{1.8}{3} + \frac{1.2}{3} = \frac{5}{3}$$

Since the result is larger than unity (or 1), one of the actions described in paragraph (b) of 50-204.10 must be taken. In this example one or more of the noise levels related to the "C" values

must be reduced so that the total equation result will be equal to or less than 1, or personnel must be removed during one or more of the excessive noise periods. If the machine producing 97 dB(A) is mechanically corrected (by methods such as balancing or re-alignment) so that its noise is reduced to 89 dB(A), only C2/T2 and C3/T3 are used in the equation, or:

$$\frac{0.3}{0.5} + \frac{0.10}{0.25} = \frac{1.8}{3} + \frac{1.2}{3} = \frac{3}{3} = 1$$

Since this result is not greater than 1, there is no restriction of the amount of time personnel can be in the area in the eight-hour shift.

Documentation

Regardless of the type of personnel- or agency-related noise problems being dealt with, records of all measurement data, actions taken, and results obtained should be carefully maintained. Such documentation can be vital in noise-related legal action against the Company. It can also be of major significance in dealing with Local, State or Federal noise control enforcement agents.

MAINTENANCE

BATTERY REPLACEMENT

Remove battery compartment cover (on switch side of meter). Slide the tray containing the batteries from the tray and remove snap-on connectors. Install connectors on new pair of batteries. (Always replace batteries in pairs.) Place batteries in tray and return tray to compartment. Replace compartment cover. Select any measurement mode, depress TEST pushbutton, and confirm readout in TEST area of meter. Turn meter off.

TROUBLESHOOTING

If a problem occurs with the Model 308, it should be turned over to an experienced electronics technician for troubleshooting. The schematic (figure 26) in this section is included as an aid to the technician in locating the trouble. Test signals for troubleshooting may be introduced as described under "Calibration."

If the trouble cannot be determined, return the meter to the factory; include the pickup cable and both transducers with the meter; exclude items such as manual, pickup holders, etc. (The Model 308 carrying case provides the safest and most practical container for return shipment. Use exterior carton to protect carrying case.)

ACCURACY TEST - SOUND

Use the Mechanalysis Sound Level Calibrator (Part No. 9404) to check the Model 308 A, B and C measurement modes for readout accuracy at least once

each month. If desired, the accuracy test may be made on a daily or per-usage basis, and particularly before making an important series of measurements for comparison with Local, State or Federal noise control "Standards." Proceed as follows:

1. Install microphone in meter receptacle. Set range selector to "110" and select mode A. Check batteries using TEST function.

2. "Start" sound level calibrator and set for frequency of 1000 Hz. Install calibrator on microphone.

NOTE

Observe operating procedures given in calibrator manual for 1-1/8" diameter microphones (General Radio 1560-P1, -P3, -P4; Shure 9898, 98108). In particular, observe instructions for "Altitude and Pressure Corrections" in the manual, and apply if necessary.

3. Confirm meter readings within limits given below for each measurement mode; alter 113.8 basic value with pressure or altitude corrections if necessary. If any mode is not within tolerance, calibrate meter.

<u>MODE</u>	<u>BASIC VALUE (dB)</u>	<u>TOLERANCE (dB)</u>
A	113.8	<u>± 2</u>
B	113.8	<u>± 2</u>
C	113.8	<u>± 1.5</u>

CALIBRATION

Calibration Period

Calibration of all measurement modes of the Model 308 should be accomplished at least every 12 months or whenever meter readings are known to be in error.

Test Equipment Required

The following test equipment (or the equivalent) is required; equipment used must be properly calibrated to obtain accurate results:

Sound Level Calibrator: Mechanalysis Part No. 9404.

Audio-Frequency Signal Generator: Hewlett-Packard Model 200 CD or Eq.

High-Impedance (1 megohm or higher) A-C Millivoltmeter

Calibration Procedure

The calibration procedure should be performed only by an experienced electronics technician. Perform the following steps in the numerical sequence given:

NOTE

Model 308 has an access hole provided on the left side, for adjustment (step 9) of the SOUND CAL potentiometer P2.

If sound level calibration only is to be performed, disregard disassembly instructions in steps 1-5. (Set range selector to "110.") Perform steps 6, 7, 8. Remove cap on access hole on the left side. Perform step 9.

1. Remove battery compartment cover.

2. Set range selector to "110" (red number). Loosen two Allen-head setscrews on range selector knob and remove knob.

3. Remove three screws holding front panel to chassis. Remove panel carefully to avoid stress on panel-to-chassis wiring; position panel so that amplitude meter can be easily seen.

4. Temporarily re-install range switch knob, without changing switch setting.

5. An adjustment tool or small screwdriver is required. The adjustment potentiometers and locations are identified in the schematic, Fig. 26.

6. Install microphone in meter receptacle.

7. Select mode C, and check batteries using TEST function.

8. "Start" sound level calibrator and set for frequency of 1000 Hz. Install calibrator on microphone.

NOTE

Observe operating procedures given in calibrator manual for 1-1/8" diameter microphones (General Radio 1560-P1, -P3, -P4; Shure 9898, 98108). In particular, observe altitude and pressure correction data in the manual, and apply if necessary.

9. Adjust SOUND CAL potentiometer P2 to obtain a meter reading of exactly 113.8 dB (or 113.8 dB plus or minus temperature or pressure corrections, if applicable).

10. Select modes A and B and confirm a meter reading within ± 2 dB of the step 9 calibration value, for each mode. If reading is not within tolerance for either mode (A or B), return meter to factory - see "Troubleshooting."

11. Connect a 100K ohm resistor across pins A and B of ANALYZER connector. Connect a-c millivoltmeter across 100K ohm resistor (or across pins A and B).

12. Adjust OUTPUT CAL potentiometer P4 to obtain a voltmeter reading of 374 millivolts rms (or 147.5 millivolts rms for Model 308M).

13. Disconnect millivoltmeter and 100K ohm resistor.

14. Remove calibrator from microphone and turn calibrator off.

15. Remove microphone from meter and depress OFF pushbutton.

16. Turn range selector to the third position clockwise from the "110" dB setting; this is the "1" range for velocity or displacement (or "30" range on Model 308M).

17. Obtain signal generator and a-c millivoltmeter. Connect generator "signal output" terminal to pin 2 of MICROPHONE/PICKUP receptacle. Connect generator "signal return" to pin 1 of meter receptacle. Connect voltmeter across generator output.

18. Set generator output frequency at 318 Hz. Adjust output amplitude to 764 millivolts as indicated on voltmeter (see note).

NOTE

- The Model 308 is normally calibrated for velocity readout in inches/second peak value. If meter is to be calibrated for velocity readout in inches/second rms value, set generator output amplitude to 1.080 volts in step 19.
- If meter is calibrated to read velocity in inches/second rms, multiply velocity readings by 1.4 to use Vibration Severity Chart (figure 9 or 10) or Dominant Frequency Chart (figure 11). For Dominant Frequency formula use:

$$\text{DOMINANT FREQUENCY} = \frac{V \text{ (rms)} \times 1.4}{D \text{ (Peak-to-peak)}} \times 19,120$$

19. Select VEL mode on Model 308 and allow 2 or 3 minutes for equipment warmup; recheck generator output amplitude.

20. Adjust VEL CAL potentiometer P1 to obtain a meter reading of exactly 1 on the upper 0 to 1 scale (or exactly 2.54 on the 0 to 3 scale for Model 308M).

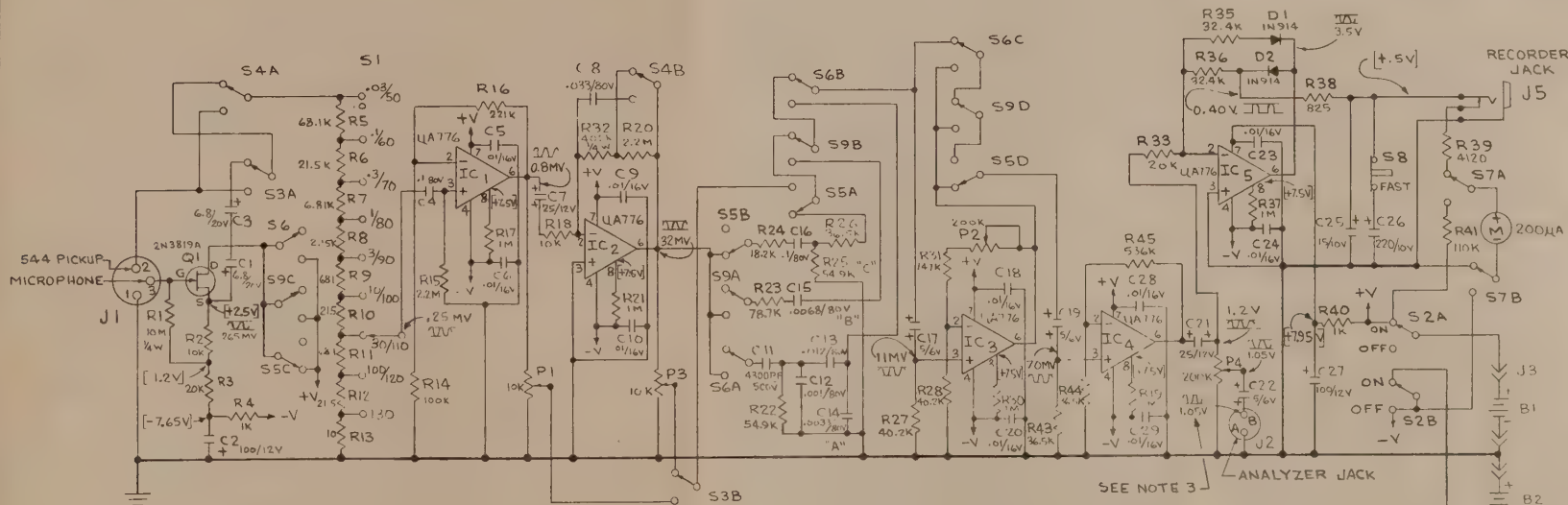
21. Recheck generator output amplitude to be 764 millivolts; do not change frequency.

22. Select DISP mode and allow 1 minute for meter to stabilize. Adjust DISP CAL potentiometer P3 to obtain a meter reading of exactly 1 on the upper 0 to 1 scale (or exactly 2.54 on the 0 to 3 scale for Model 308M).

23. Turn off Model 308 and all test equipment, and disconnect setup.

24. Reassemble meter in reverse order of disassembly.

LTR.	REVISION	CHANGE ORDER	C.K.D. DATE	APP.D. DATE
(A)	REDRAWN & REDESIGNED FOR NEW IC'S (POTS. AFFECTS UNITS S/N 175 UP 12)		5-2-72	5-2-72



PARTS LIST

<u>MAJOR ASSEMBLIES AND ACCESSORIES</u>	<u>PART NO.</u>
Model 308 Vibration/Sound Level Meter	0068
Case, Carrying	9375
Instrument Assembly	9285
Microphone	5294
Vibration Pickup, Model 544	4526
Probe, Straight	1103
Cable Assembly, 6-foot Retractable	9288
Strap, Leather	3829
Cap, ANALYZER Connector	9311
Plug, RECORDER Connector	9361
Operation and Maintenance Manual	----

CIRCUIT COMPONENTS

Letters in Circuit Symbols in the components list have the following definitions:

B - Battery	M - Meter
C - Capacitor	P - Potentiometer
D - Diode	Q - Transistor
IC - Integrated Circuit	R - Resistor
J - Connector	S - Switch

<u>CIRCUIT SYMBOL</u>	<u>DESCRIPTION</u>	<u>PART NO.</u>
B1, B2	8.4V Mallory TR146X	9291
C1	0.022 uF 10% 80V	5042
C2	100 uF 12V	3605
C3	5 uF 6V N.P.	3490
C4	0.1 uF 100V	4574

<u>PART NO.</u>	<u>CIRCUIT SYMBOL</u>	<u>DESCRIPTION</u>
9284	C5, C6	0.01 uF 16V
5464	C7	25 uF 12V N.P.
9336	C8	0.033 uF 5% 80V
9284	C9, C10	0.01 uF 16V
9279	C11	4300 pF 5% 500V
9335	C12	0.0033 uF 5% 80V
9334	C13	0.012 uF 5% 80V
9335	C14	0.0033 uF 5% 80V
9300	C15	0.0068 uF 5% 80V
9342	C16	0.1 uF 5% 80V
3490	C17	5 uF 6V N.P.
9284	C18	0.01 uF 16V
5391	C19	470 pF 5% 500V
9284	C20	0.01 uF 16V
5464	C21	25 uF 12V N.P.
3490	C22	5 uF 6V N.P.
9284	C23, C24	0.01 uF 16V
5396	C25	6.8 uF 20V
3605	C26, C27	100 uF 12V
7402	C28	220 pF 5% 500V
5398	D1, D2	1N914
9269	IC1, IC2	uA776
9234	IC3	MP112
9269	IC4	uA776
9235	J1	MICROPHONE/PICKUP Input
8731	J2	ANALYZER Output
9264	J3, J4	Battery Snap-on, Polarized
9360	J5	RECORDER Output
9259	M1	200 uA Amplitude
5579	P1	10 K-ohm 89WR10K
9276	P2	500 K-ohm 89WR500K
5579	P3	10 K-ohm 89WR10K
5064	P4	(1) 20 K-ohm Type 62P

(1) Used on Model 308 only

<u>PART</u> <u>NO.</u>	<u>CIRCUIT</u> <u>SYMBOL</u>		<u>DESCRIPTION</u>
5125	P4	(2)	200 K-ohm Type 62P
8556	Q1		2N3819A FET
7877	R1		10 M-ohm 5% 1/4W
7859	R2		10 K-ohm 1% 1/8W
9274	R3		20 K-ohm 1% 1/8W
7848	R4		1 K-ohm 1% 1/8W
7867	R5		68.1 K-ohm 1% 1/8W
7862	R6		21.5 K-ohm 1% 1/8W
7857	R7		6.81 K-ohm 1% 1/8W
7851	R8		2.15 K-ohm 1% 1/8W
7846	R9		681 Ohm 1% 1/8W
7844	R10		215 Ohm 1% 1/8W
7842	R11		68.1 Ohm 1% 1/8W
9270	R12		21.5 Ohm 1% 1/8W
7840	R13		10 Ohm 1% 1/8W
7868	R14		100 K-ohm 1% 1/8W
9298	R15		2.2 M-ohm 1% 1/8W
9282	R16		221 K-ohm 1% 1/8W
9267	R17		1 M-ohm 1% 1/8W
7859	R18		10 K-ohm 1% 1/8W
----	R19		not used
9298	R20		2.2 M-ohm 1% 1/8W
9267	R21		1 M-ohm 1% 1/8W
7866	R22		47.5 K-ohm 1% 1/8W
8440	R23		90.9 K-ohm 1% 1/8W
7861	R24		18.2 K-ohm 1% 1/8W
9275	R25, R26		36.5 K-ohm 1% 1/8W
8675	R27, R28		40.2 K-ohm 1% 1/8W
9266	R29		536 K-ohm 1% 1/8W
9283	R30		301 K-ohm 1% 1/8W
9265	R31		3.65 M-ohm 1% 1/8W
----	R32		not used
8458	R33		11.5 K-ohm 1% 1/8W

(2) Used on Model 308M only

<u>CIRCUIT</u> <u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>PART</u> <u>NO.</u>
R34	not used	----
R35, R36	32.4 K-ohm 1% 1/8W	9273
R37	1 M-ohm 1% 1/8W	9267
R38	2 K-ohm 1% 1/8W	7850
R39	7.87 K-ohm 1% 1/8W	9281
R40	1 K-ohm 1% 1/8W	7848
R41	121 K-ohm 1% 1/8W	8681
R42	17.4 K-ohm 1% 1/8W	9468
S1	Range Selector	9258
S2-S7, S9	(3) Mode Selector Assembly	9260
S8	FAST Response	9237

(3) See Schematic for individual switch functions

